Report to the Congress

on the

STRATEGIC DEFENSE INITIATIVE

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FIGURES

TABLES

LIST OF ACRONYMS

ABM	Antiballistic Missile
ACS	Attitude Control System
ADOP	Advanced Distributed Onboard Processor
AOA	Airborne Optical Adjunct
AOS	Airborne Optical Sensor
ASAT	Antisatellite
ATBM	Anti-tactical Ballistic Missile
ATP	Acquisition, Tracking and Pointing
ATP-FC	Acquisition, Tracking, Pointing and Fire Control
BM	Battle Management
BM/C^3	Battle Management/Command, Control and Communications
BMD	Ballistic Missile Defense
BMDPM	Ballistic Missile Defense Program Manager
BSTS	Boost Surveillance and Tracking System
C^2	Command and Control
C^3	Command, Control and Communications
CONUS	Continental United States
CW	Continuous Wave
DARPA	Defense Advanced Research Projects Agency
DEW	Directed Energy Weapons
DF	Deuterium Flouride
DNA	Defense Nuclear Agency
DoD	Department of Defense
DoE	Department of Energy
DRB	Defense Resources Board
DSDIO	Director, Strategic Defense Initiative Organization
DSP	Defense Support Program
DST	Defense Suppression Threat
DTS	Defensive Technology Study
ECM	Electronic Countermeasure
EMP	Electromagnetic Pulse
ERIS	Exoatmospheric Reentry Vehicle Interception System
FCRC	Federal Contract Research Center
FEL	Free Electron Laser

FS^3	Future Strategic Strategy Study
FY	Fiscal Year
GAO	General Accounting Office
GBHRG	Ground-Based Hypervelocity Rail Gun
GBL	Ground-Based Laser
HEDI	High Endoatmospheric Defense Interceptor
HEDS	High Endoatmospheric Defense System
HELSTF	High Energy Laser Systems Test Facility
HIBREL	High Brightness Relay
HOE	Homing Overlay Experiment
ICBM	Intercontinental Ballistic Missile
IEG	Independent Evaluation Group
IR	Infrared
IRBM	Intermediate-Range Ballistic Missile
IST	Innovative Science and Technology
ITD	Integration Test and Demonstration
KEW	Kinetic Energy Weapon
KJ	Kilojoules
KKV	Kinetic Kill Vehicle
KMR	Kwajalein Missile Range
L&TH	Lethality and Target Hardening
LADAR	Laser Radar
LAMP	Large Advanced Mirror Program
LODE	Large Optics Demonstration Experiment
LODTM	Large Optics Diamond Turning Machine
LRINF	Longer-range, Intermediate-Range Nuclear Forces
LWIR	Long Wavelength Infrared
MARV	Maneuvering Reentry Vehicle
MIRACL	Mid Infrared Advanced Chemical Laser
MIRV	Multiple Independently-Targeted Reentry Vehicles
MKV	Miniature Kill Vehicle
MMW	Multimegawatt
MT	Metric Ton
NASA	National Aeronautics and Space Administration
NCC	Noncancellable Commitments
NDEW	Nuclear Directed Energy Weapon

NPB	Neutral Particle Beam
NTB	National Test Bed
NTF	National Test Facility
NTM	National Technical Means
OASD/ISP	Office of the Assistant Secretary of Defense for International Security Policy
OJCS	Office of the Joint Chiefs of Staff
PBV	Post-Boost Vehicle
PCM	Pyrotechnic Countermeasure
PPBS	Planning, Programming and Budgeting System
R&D	Research and Development
RFL	Radio-Frequency Linac
RFP	Request for Proposal
RV	Reentry Vehicle
SA/BM	System Analysis and Battle Management
SAL	Strategic Arms Limitation
SALT	Strategic Arms Limitation Talks
SATKA	Surveillance, Acquisition, Tracking and Kill Assessment
SBHRG	Space-based Hypervelocity Rail Gun
SBIR	Small Business Innovative Research
SBKKV	Space-Based Kinetic Kill Vehicle
SBL	Space-Based Laser
SBNPB	Space-Based Neutral Particle Beam
SBPB	Space-Based Particle Beam
SDC	Space Defense Command
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
SGEMP	System Generated Electromagnetic Pulse
SLBM	Submarine-Launched Ballistic Missile
SLKT	Survivability, Lethality and Key Technologies
SPADATS	Space Detection and Tracking System
SSTS	Space Surveillance and Tracking System
STA	Science and Technology Agent
TBM	Tactical Ballistic Missile
TIR	Terminal Imaging Radar
TVE	Technology Verification Experiment

TW/AA	Tactical Warning/Attack Assessment
USDRE	Under Secretary of Defense for Research and Engineering
UV	Ultraviolet
WSMR	White Sands Missile Range

CHAPTER I

INTRODUCTION

A. PURPOSE OF REPORT

This report describes the coordinated Department of Defense (DoD) research and technology program efforts needed to meet the goals of the President's Strategic Defense Initiative (SDI). This report responds to Section 1102 of the Department of Defense Authorization Act, Fiscal Year 1985, (Public Law 98-525, October 19, 1984).

B. SCOPE

The scope of this report encompasses the plans for on-going and future efforts by the DoD to achieve the goals of the SDI. This plan describes the basic program execution by DoD Services, Agencies, and the Strategic Defense Initiative Organization (SDIO). The basic program comprises all SDI supported research and technology efforts leading to decisions on whether or not to implement a defensive strategy and develop promising systems for defense against ballistic missiles. This report is designed to serve as a basic tool in communicating a broad overview of the SDIO Program to non-SDIO agencies and groups.

C. PROGRAM GENESIS

In March 1983, the President called for an intensive and comprehensive effort to define a long term research technology development program with the ultimate goal of eliminating the threat posed by nuclear ballistic missiles. Two study teams were established, the Future Strategic Strategy Study (FS^3) Team and the Defensive Technology Study (DTS) Team. The DTS, commonly referred to as the Fletcher Study, called for the structuring of a broad-based research and technology development effort focused on establishing technical feasibility, as opposed to initiating system-level development. The recommended effort was structured to permit a decision in the early 1990s on

whether to proceed to system-level development. The FS[3], which paralleled the Fletcher Study, concluded that it was essential that options for the deployment of advanced defenses against the ballistic missile be established and maintained. Such defenses, if feasible, would offer an entirely new concept of deterring nuclear war based on defense against attack rather than solely relying on retaliation.

In January 1984, the Strategic Defense Initiative was established as a research program based on the Fletcher Study. In the same time frame, the Strategic Defense Initiative Organization (SDIO) was formed as a defense agency to manage the DoD efforts. Specifically, a comprehensive SDI program was defined to explore key technologies associated with concepts for defense against ballistic missiles. The SDIO was directed to place principal emphasis on technologies involving nonnuclear kill concepts. (Research on nuclear directed energy weapons is being undertaken by the Department of Energy separately from the efforts of the SDIO to develop an understanding of the potential of this technology and as a hedge against Soviet work in this area.) At the same time, the SDI program protects options to deploy a limited defense against ballistic missiles (nonnuclear if possible) as one possible early response to particularly threatening Soviet deployments.

Specific research efforts were organized in five areas:

- Surveillance, Acquisition, Tracking, and Kill Assessment (SATKA)
- Directed Energy Weapons (DEW) Technologies
- Kinetic Energy Weapons (KEW) Technologies
- Systems Analysis and Battle Management (SA/BM)
- Survivability, Lethality, and Key Technologies (SLKT)

CHAPTER II

THE DIRECTOR'S OVERVIEW

A. INTRODUCTION

Fiscal Year 1985 was a challenging and exciting year for the Strategic Defense Initiative Organization. Efforts were most inventive and innovative, and events moved very quickly. That challenge and movement have extended into FY 1986. The following themes best characterize these early and formative years:

- The shaping of the program to a better understanding of the ultimate needs and the likely fiscal constraints plus our ability to formulate an investment strategy that allows us to reach our goals in light of those needs and constraints.

- The emergence of new opportunities and the beginnings of important progress in our technical program that provide the foundations for the major decisions we see in the future.

- The beginnings of a convergence of the key concerns and issues in the important national debate on the Initiative.

My overview will concentrate on these three points. They provide the basic evidence to the Congress, the nation, and our Allies that the Strategic Defense Initiative has passed through the usual turbulence associated with the formative years of any major new endeavor. We have plotted a course and are now well underway. The SDIO is proceeding with a focused, goal-oriented program to support critical national decisions about the future thrust of the nation's strategy, policy, and tactics in the presence of nuclear weapons. The details that follow in this Annual Report to the Congress describe the technical and programmatic aspects of our program and present key discussions

on cooperative efforts with our Allies, arms control, and responsive threats.

We are committed to the President's policy to conduct our program within the bounds of existing treaties and international agreements to which the nation is a party. We have, therefore, chosen to describe the program in terminology compatible with the use and interpretations of language appearing in those treaties, particularly the Anti-Ballistic Missile (ABM) Treaty. In doing so, we preempted the lexicon of the research and development community in favor of the terminology found in international agreements. This has been done not only to underscore our commitment to existing treaties and agreements, but also to promote understanding by confining the discussion of SDI to one "word set". The differences in meaning between technical and political language are often great. For example, the ABM Treaty refers to a component as "currently consisting of" an ABM radar, ABM launcher, or ABM interceptor missile. The R&D community uses "component" to describe any part, constituent or ingredient including one of the smallest elements (such as a switch) that makes up a subsystem that in turn makes up a system such as a radar, etc. (Appendix C and D contain a more detailed discussion of terminology.)

B. SHAPING THE PROGAM

At the beginning of FY 1985, we were in the midst of starting this major new effort with three basic tasks. First, we needed to ensure continuity in those programs inherited from the Services that were appropriate and relevant to the Initiative. Second, we had to tailor other inherited programs to better fit the needs of our endeavor. Third, we had to initiate important new programs that both expanded and accelerated the pre-SDI efforts in ballistic missile defense and related technologies. We had a basic sketch of the program from the studies done in the Summer of 1983, a well-established goal, and an investment strategy that pushed promising technologies across a broad front

and at a pace that was limited, not by funds, but by the pace at which that technology could be developed in an efficient program that controlled risk.

Section IV states our program goals and technical objectives, describes how we have constructed our program in reaction to the realities of budget allocations by the Congress and outlines our evolving understanding of the technology needed to realize our goal. We have made substantive changes in the program as the result of these pressures. Therefore, I would like to give you a brief overview of the structure of our program, our current investment strategy and the changes made to the program.

Although our budget requests for FY 1985 and FY 1986 were reduced by the Congress by about 25 percent, we have made adjustments without changing our basic goal. Although we now have to accept higher risks and more austere research, we still seek to provide the basis for informed decisions in the early 1990s on whether or not to develop and later deploy a defense of the United States and its Allies against ballistic missiles. The mission of the SDIO is to provide the widest set of technical options that time and the resources allocated will permit. We seek the technology that can support a decision to pursue defensive options that would provide an effective defense of critical assets, of our nation and our Allies. But most importantly we seek to lessen the possibility of nuclear war. In essence, we seek to provide strategic defense options that would eliminate the threat posed by ballistic missiles, and thereby;

- Support a better basis for deterring aggression;
- Strengthen strategic stability;
- Increase the security of the United States and our Allies.

We have established our goal in the belief that technological progress can yield the results we seek in the time frame set. We also believe that a program that does not aim toward providing the basis for a development decision at a particular time is likely to lose its focus, its dedication to its goals, and its support.

To accomplish our mission, the SDIO has established a program that has three basic building blocks:

- A technology base program that includes over 50 percent of the scientific work of the SDIO. It is comprised of both basic and applied research intended to foster the birth of many innovative ideas, provide the needed framework of knowledge to pursue large projects, and build opportunities for program growth.

- Technology integration (proof-of-feasibility) experiments are intended to show the feasibility of key technologies. Emphasis is on the early resolution of major issues that, if resolved favorably, can have a substantial impact on the success of ballistic missile defenses over the long term.

- Demonstration-of-capabilities projects involving technology that has already been demonstrated as feasible and must now be integrated with other subsystems to show that desired performance levels can be achieved. These projects emphasize integration of constituent elements and the performance of functional tests to bring feasible technology into engineering proof-of-principle. Full defensive capability need not be tested to prove feasibility.

Given these three basic thrusts within the SDIO research program, the establishment of an investment strategy for the SDIO has been of major importance.

The large budget reductions imposed by the Congress have forced us continually to reevaluate our priorities. Our current investment strategy:

- Protects the technology base,
- Increases the emphasis on proof-of-feasibility experiments with increased investment in the high risk-high payoff approaches, and
- Decreases the number and scope of capability demonstration projects.

This strategy seeks an end product that gives the U.S. the kind of leverage necessary to make SDI work and work effectively at a reasonable cost. Admittedly, this involves a higher element of risk, and we need to maintain a constant vigil over the priority settings between the technology base and feasibility experiments. The program can afford neither to pursue "science for the sake of science" nor to proceed with risky experiments having an inadequate technology base.

The impact of the budget cuts has been pervasive at a time when technology is moving forward rapidly and there is a need to emphasize certain technical areas originally underemphasized or overlooked.

The demonstration-of-capabilities activities are configured into an experimental mode emphasizing key technology issues rather than the integration aspects:

- Space Surveillance Tracking System (SSTS),
- High Endoatmospheric Defense Interceptor (HEDI),
- Exoatmospheric Reentry Vehicle Interceptor Subsystem (ERIS),
- Terminal Imaging Radar (TIR), and
- Integration Test and Demonstration Project (ITD).

On the other hand, the following areas have been selected for greater emphasis in achieving proof-of-feasibility at an early date:

- Ground-based free electron laser technology integration experiment,
- Space-based neutral particle beam technology integration experiment,
- Space-based kinetic energy technology experiments, and
- A set of space pointing and tracking experiments.

These experiments, upgraded into projects, are a natural outgrowth of the SDIO's emphasis on critical path programs. They are oriented toward resolving the key issues needed for possible development decisions in the early 1990s. They will also provide a timely, visible, and understandable set of milestones to measure program progress and accomplishment.

The key to the success of this approach is to incorporate multiple paths to successful operation and thus avoid single point failures. The reduction of the requested budget levels by Congress has not, as yet, had the effect of slowing project schedules for the present proof-of-feasibility experiments. It has had the effect, however, of not allowing the SDIO to fund the alternative or fall-back technologies at an adequate level to minimize program risk. In addition, it has caused us to reduce considerably the pace of many of our demonstration-of-capability programs.

Thus, Congressional budget reductions have had an adverse impact on SDI research and forced major program changes. We have been forced to reduce the effort on certain major technologies such as space-based lasers prematurely. This will increase significantly program risk and could cause program slippage, thereby delaying completion and increasing total costs.

C. NEW OPPORTUNITIES: THE BEGINNINGS OF PROGRESS

One of our top priorities has been to examine multilayer defense architectures and define major factors affecting technology decisions, such as threat, survivability, lethality, and affordability. We need to have the best possible understanding of these issues so that we can chart a clear course for the program. Even though the resources devoted to this particular work are relatively modest, the importance of the results cannot be overstated. Nearly every element of SDIO's research is touched.

By late FY 1985, Phase I of the System Architecture and Tradeoff Study was completed by ten industrial contractor teams. Classes of potential architectures for ballistic missile defense were identified and key issues in achieving those architectures explored. Phase II, with the number of contractors reduced to five, is examining the classes of architectures and issues in greater detail. While we have found a healthy diversity of opinion on how to resolve key issues, we also expect agreement on the key features of ballistic missile defense architectures. Points of major importance that have emerged are:

- The most robust architecture would combine both space- and ground-based elements. The space-based assets would be configured to provide effective defense during the boost, post-boost, and midcourse phases of the threat trajectory. They also would provide self defense and protect against various defense suppression threats. The ground-based components would be used to engage the threat during the late midcourse part of the threat trajectory and within the atmosphere at both high and low altitudes. The large number of opportunities to engage the threat with this architecture leads to an expectation of achieving very low levels of defense leakage even if the enemy were to proliferate his offensive forces in response to our defense.

- We must fully explore technologies that could provide systems to engage hostile ballistic missiles in the boost and post-boost phases. The leverage afforded by defensive action at these stages of a hostile ballistic missile's flight can be decisive. Conceivably, the highest payoff and the greatest return on defensive dollar investment would occur in these phases, before deployment of a missile's warheads and associated penetration aids.

- Data handling, along with command and control technologies, for layered defenses must maintain a high priority within the SDI program. Clearly, this work is central to the concept of a layered defense against ballistic missiles. No matter what evolves from our research in other areas of the program, reliable, resilient and responsive data handling and command and control capabilities are requisite.

- Beyond the boost and post-boost realm, a high priority is to conduct thorough examinations of potential capabilities in other layers. The capability to perform defensive engagements in the midcourse and terminal phases is critical to the full exploitation of the advantages of a layered defense. These capabilities would also make available to our future leaders the widest range of defensive options.

- Good exoatmospheric discrimination is essential to effective midcourse defenses. In addition, midcourse defense with good discrimination capability can reduce the impact of fast burn boosters on the effectiveness of boost phase intercept. Cost-effective intercept in midcourse requires a capability to recognize light decoys (less than 1 percent of the weight of a warhead). Denying the use of light decoys exacerbates

the difficulties that fast burn boosters have in deploying decoys. Thus, the impact of this countermeasure on boost phase intercept is mitigated by the increase in effectiveness of midcourse intercept. Then, a capability for heavy decoys (1 to 10 percent) that more closely resemble the warhead can tip the cost exchange heavily in favor of the defense.

- It is hard to overestimate the importance of the generation of realistic threat models, the estimation of the vulnerability of targets to the numerous kill mechanism options being exploited, and the development of the strategies, tactics and technology to ensure system survivability to mission completion. These analyses and estimates will provide the boundaries for measuring success.

- Success in nearly every element of the program is dependent on major advances in supporting technologies for space-based electric power, power conditioning, low cost devices, space transportation and logistics.

- We must accelerate examination of potential applications to the short-range threat. Our security is inextricably linked to that of our Allies. We cannot confine ourselves solely to an exploration of technologies with promise against intercontinental range, land- and sea-launched ballistic missiles.

The architecture studies reinforce our views on the role of boost phase intercept; discrimination of decoys from warheads; midcourse and terminal intercept; basing of defense assets in space; command, control, communications and battle management; and threat modeling, survivability, and target vulnerability. At the same time, our research has already yielded important results from efforts specifically addressing these issues. (The details are included in Section VII.)

- In discrimination there is outstanding progress in imaging due to phased-array radar technology and signal processing improvements. Equally important, directed energy efforts have provided "interactive" discrimination. Using this technique, signatures can be induced from objects in space that yield specific discriminants.

- The surveillance and sensor program areas have witnessed impressive progress. Miniaturization and advances in optical sensors have provided rapid gains in surveillance technologies. Multispectral measurements of booster, post-boost vehicle, and reentry vehicle signatures have been obtained by both optical and radar devices. These measurements allow us to understand threat signatures and will be used in the development of sensor technology. Additionally we have achieved significant progress in technologies for hardening of high density microelectronic processors and infrared (IR) focal plane arrays against the effect of nuclear radiation that would be experienced during a battle.

- In the directed energy field, work with atmospheric compensation and free electron laser technologies has progressed to the point where it appears that the potential for large, effective ground-based laser systems is very real.

- In electromagnetic accelerator or "rail gun" research we have shown the ability to input high levels of power to these devices far sooner than expected. This means that heavier projectiles could be used and/or higher speeds attained.

- In space-based kinetic energy weapons for boost-phase intercept, we have defined a concept for a simple chemical rocket based on low risk attainable technology at an affordable cost that would be effective in a near term defense.

- In kinetic energy weapons, the most significant accomplishment over the last 2 years has been the mid-course intercept of an actual reentry vehicle by an autonomous terminal homing interceptor. This experiment proved the capability of a nonnuclear interceptor launcher from a fixed ground position to demolish an incoming ballistic missile payload outside the earth's atmosphere at a closing speed of over 20,000 miles per hour.

- In hardening electronic circuits and devices for computers against nuclear radiation, we have fabricated and tested radiation-hardened, large scale, integrated circuits that show the potential for incorporating significant onboard processing for spacecraft in high radiation environments.

- A new radar has been developed and deployed that improves the capability of collecting detailed data on missile tests.

- A distributed computer that networks several standard commercial computers into a virtual memory system is now operational. It is providing test beds for battle management concepts.

- In lethality and target hardening, we have conducted many tests to analyze and quantify damage effects and vulnerabilities to radiation and high speed projectiles. One of the more graphic tests involved

destruction of a rocket body by a laser on a ground range. Other tests have examined the effects of x-rays on laser mirrors. Other effects tests have shown that small plastic projectiles travelling at 7 km/sec and impacting aluminum can create major damage.

We can also show progress in our dealings with our Allies. Many of our Allies have indicated support for SDI research and in some cases interest in participating. On December 6, 1985, the Secretary of Defense and the British Defense Minister signed a government-to-government agreement concerning SDI research involvement, and other Allied governments appear interested in similar accords.

U.S. and Allied security remains indivisible and we will continue to work closely with our Allies to ensure that, as research progresses, Allied views are carefully considered. In addition to direct Government participation in the research effort, Allied contributions could include innovative university research, individual exchanges, subcontracts from U.S. industry, or direct contractor arrangements. (Appendix B contains a more detailed discussion of the SDI and the Allies.)

D. SETTING OBJECTIVES AND STANDARDS

Earlier I characterized the events of the past year as the beginning of a convergence of the key concerns and issues in the important national debate on the Initiative and the promise of greater relevance in future discussions.

The stack of press and periodical coverage of SDI is now nearly two yards high, but I am pleased to report that the debate is focusing on the achievements needed before decisions can be made. A U.S. decision about whether to incorporate defenses into our strategic posture will be based on those criteria that we apply to all important military system deployment decisions:

Military Uses of Space: 1946-1991

Published by:
Chadwyck-Healey Inc., 1101 King Street, Alexandria, Virginia 22314

Military Uses of Space: 1946-1991 provides a detailed record of the strategic importance of the U.S. military space program from the conceptualization of the uses of space to the present realization of advanced capabilities. Materials were identified, obtained, assembled, and indexed by the National Security Archive, a non-profit, Washington, D.C. based research institute and library. The microfiche collection is accompanied by Military Uses of Space: 1946-1991 Guide and Index.

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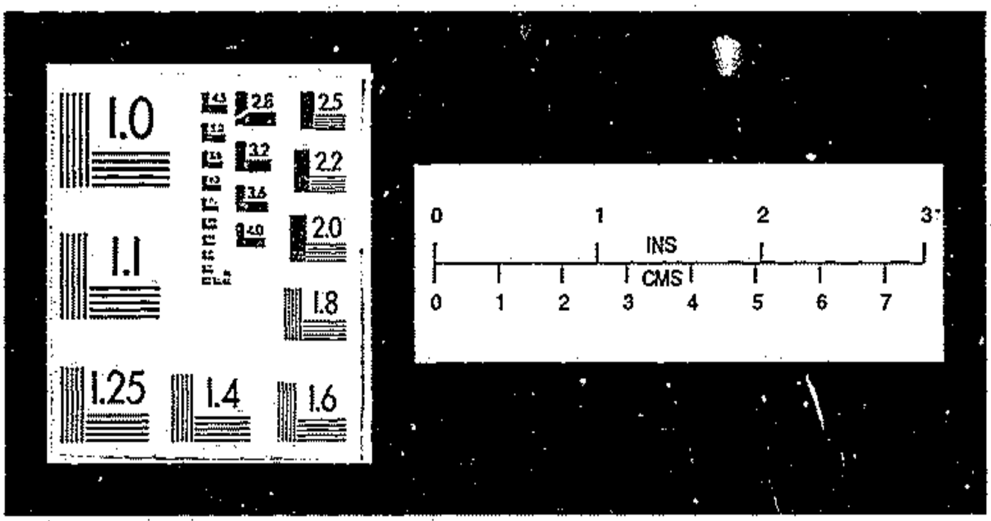

Document Quality:

- Potential Role in U.S. Strategy,
- Deterrent to Surprise Attack and Enemy Escalation,
- Contribution to Our Arms Control Objectives, and
- Technical Feasibility.

The SDIO has the lead role in defining the feasibility and cost. We also have an active role in assisting those who are addressing the other criteria to ensure our results are useful and responsive. How we view the relative weights and priorities of these criteria cannot be fixed in time; the degree to which we are successful in defining feasibility and affordability will be a major factor in future decisions.

In our role of defining feasibility and cost, we have structured our efforts to support an early 1990s decision on whether to proceed with confidence along a development path. In other words, the majority of effort needed from that point on should be engineering in nature rather than experimental. The mission and performance envelopes should be adequately defined. The best technical approach should have been selected. Finally, cost and schedule estimates should be credible and acceptable. For these conditions to be present, concept formulation and technical feasibility studies would have to be favorably completed so that questions regarding prospects for achieving the desired goals and potential pay-offs could be answered with reasonable certainty.

There is one other important point of agreement that needs to be stressed. There has been much discussion concerning the relationship between scientific objectivity and partisan politics. The scientists and engineers, both inside and outside the government, involved with the Strategic Defense Initiative have an obligation to hold their professions and their work to the highest standards; that is, scientific objectivity should rise above partisan political debate. Resolution of the technology ambiguities can anchor the political arguments and will ultimately lead to an informed decision.

E. SUMMARY OBSERVATIONS

In conclusion, several cogent themes in Secretary Weinberger's Posture Statement capture the direction and scope of the program. These themes bear repeating once again.

- The aim of the SDI is to determine the feasibility of a thoroughly reliable defense against Soviet strategic and shorter-range missiles. Our research program to determine if we can do this is well under way;

- Research will last for some years. Our research program is being conducted within ABM treaty limitations, despite Soviet violation of that treaty;

- It is too early in our research program to speculate on the kinds of defensive systems--whether ground-based or space-based and with what capabilities--that might prove feasible and desirable to develop and deploy;

- The purpose of the defensive options we seek is clear--to find a means to destroy attacking ballistic missiles before they can reach their potential targets;

- United States and Allied security remains indivisible. The SDI program is designed to enhance Allied security as well as U.S. security. We will continue to work closely with our Allies;

- We are attempting to engage the Soviets in serious discussions in Geneva on how international security and stability could be enhanced through a greater reliance by both sides on advanced defensive systems;

- SDI represents no change in our commitment to deterring war;

- For the coming years, offensive nuclear forces and the prospect of nuclear retaliation will remain the key element of nuclear deterrence. Therefore, we must maintain modern, flexible, and credible offensive strategic and intermediate-range nuclear forces;

- Our ultimate goal is to eliminate nuclear weapons entirely. By necessity, this is a very long term goal, which also requires research on defenses against other nuclear threats, effective nuclear arms control agreements and equally energetic efforts to diminish the threat posed by conventional arms imbalances.

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CHAPTER III

PROGRAM IN PERSPECTIVE

A. THE STRATEGIC CONTEXT

The basic intent behind the SDI is best explained and understood in terms of the strategic environment the United States faces for the balance of this century and into the next. This nation and those nations allied with it face a number of challenges to their security. Each of these challenges imposes its own demands and presents its own opportunities. Preserving peace and freedom is, and always will be, this country's fundamental goal. The essential purpose of its military forces is to deter aggression and coercion based upon the threat of military aggression. The deterrence provided by U.S. and Allied military forces in the past has permitted the American people and our Allies to enjoy peace and freedom.

For the past 20 years, assumptions of how nuclear deterrence can best be assured have been based on one basic idea. That is, if each side maintains the ability to retaliate against any attack and impose on an aggressor costs that are clearly out of balance with any potential gains, this threat will suffice to prevent conflict. The estimate of what United States forces have had to hold at risk to deter aggression has changed over time. Nevertheless, the strategy of basic reliance on retaliation provided by offensive nuclear forces as the essential means of deterring aggression has not changed. This assumption served as the foundation for the U.S. approach to the Strategic Arms Limitation Talks (SALT). At the time the process began, the United States concluded that deterrence based on the capability of offensive retaliatory forces was not only sensible but necessary. We believed that both sides were far from being able to develop the technology for defensive systems which could effectively deter the other side. However, the Soviet Union has failed to show the type of restraint, in

both strategic offensive and defensive forces, that was hoped for when the strategy was implemented and the SALT process began.

The U.S. response to the strategic threat has, out of necessity, undergone a period of evolution during the last three decades in order to adapt to the changing nature of the threat itself. The current strategic environment is characterized by (1) improvements in Soviet strategic offensive and defensive forces, (2) a longstanding and intensive Soviet research program in many of the same basic technological areas which the SDI program will address, and (3) a growing pattern of Soviet deception and noncompliance with existing arms control agreements.

B. THE CHALLENGE TO U.S. SECURITY

The Soviet Union remains the principal threat to U.S. security and that of its Allies. As part of its wide-ranging effort to increase further its military capabilities, the Soviet Union's improvement of its ballistic missile force has increasingly threatened the survivability of forces the U.S. and our Allies have deployed to deter aggression and of the leadership structure that commands them. It equally threatens many critical fixed installations in the United States and in Allied nations that support the nuclear retaliatory and conventional forces which provide the collective ability to deter conflict and aggression.

Since 1969 when the SALT I process was just starting, the Soviet Union has built five new classes of intercontinental ballistic missiles (ICBMs) and upgraded these seven times. As a result, their missiles are much more powerful and accurate than they were several years ago. The United States, in contrast, introduced its last new intercontinental ballistic missile, the Minuteman III, in 1969, which has been upgraded once, and is now dismantling the obsolete Titan missiles. The alarming growth, both in quantity and quality, of Soviet ballistic

missiles over the last decade is yielding a prompt hard target force capable of rapidly and significantly degrading our land-based retaliatory capability. The resulting asymmetry between Soviet and U.S. force structures has led to a destabilizing situation, one that the Reagan Administration strongly believes must be redressed.

At the same time that it has worked to improve its offenses, the Soviet Union has continued to pursue strategic advantage through the development and improvement of active defenses. These active defenses provide the Soviet Union a steadily increasing capability to counter the retaliatory forces of the U.S. and its Allies, especially if those forces were to be degraded by a Soviet first strike. Even today, Soviet active defenses are extensive. For example, the Soviet Union possesses the world's only operational antiballistic missile sytem, deployed around Moscow. The Soviet Union currently is improving all elements of this system. The Soviets are also developing components of a new ABM system that apparently are designed to allow them to construct individual ABM sites in a matter of months rather than the years required for more traditional ABM systems. The Soviet Union also has the world's only operational anti-satellite (ASAT) capability. It has an extensive air defense network, which it is continuing to improve, and it is aggressively improving the quality of its radars, interceptor aircraft, and surface-to-air missiles. It also has a very extensive network of ballistic missile early warning radars. All of these elements provide them an area of relative advantage in strategic defense today and, with logical evolutionary improvement, could provide the foundation for a decisive advantage in the near future if the U.S. does not take steps necessary to counter these activities.

The Soviet Union is also spending significant resources on passive defensive measures aimed at improving the survivability of its own forces, military command structure and

national leadership. These efforts range from providing rail and road mobility for its latest generation of ICBMs to extensive hardening of various critical military and civil defense installations.

For over two decades, the Soviet Union has pursued a wide range of strategic defensive efforts, including advanced ABM research and development. The resulting trends have shown steady improvement and expansion of Soviet defensive capability. Furthermore, current patterns of Soviet research and development on advanced defenses indicate that these trends will continue apace for the foreseeable future. If unanswered, continued Soviet defensive improvements will further erode the effectiveness of the United States' existing deterrent, based almost exclusively on the threat of retaliation by offensive nuclear forces. Therefore, this longstanding Soviet program of defensive improvements, in itself, poses a challenge to deterrence which must be addressed.

Finally, the problem of Soviet noncompliance with arms control agreements in both the offensive and defensive areas, including the ABM Treaty, is a cause of very serious concern. Soviet activity in constructing the new phased-array radar near Krasnoyarsk, in central Siberia, has significant consequences. When operational, this radar, due to its location, and the location of others in the new network, will increase the Soviet Union's capability to deploy a territorial ballistic missile defense. Recognizing that such radars would make that contribution, the ABM Treaty expressly bans their construction at interior locations as one of the primary mechanisms for ensuring the effectiveness of the Treaty. The Soviet Union's activity with respect to this radar, due to its location and orientation, is in direct violation of the ABM Treaty.

Against the backdrop of this Soviet pattern of noncompliance with existing arms control agreements, the Soviet

Union is also taking other actions which affect this country's ability to verify Soviet compliance. Some Soviet actions, like their increased use of encryption during missile testing, are directly aimed at degrading the U.S. ability to monitor treaty compliance. Other Soviet actions, too, contribute to the problems that must be faced in monitoring Soviet compliance. For example, Soviet increases in the number of their mobile land-based ballistic missiles, especially those armed with multiple, independently-targetable reentry vehicles, and other mobile systems, will make verification less and less certain. If the United States fails to respond to these trends, there may come a point in the foreseeable future where the U.S. would have little confidence in its assessment of the state of the military balance or imbalance, with all that implies for the country's ability to control escalation during crisis.

C. RESPONDING TO THE CHALLENGE

In response to the long term pattern of Soviet offensive and defensive improvements, the United States is compelled to take complementary actions designed both to maintain security and stability in the near term and to ensure these conditions in the future. It must act in three main areas.

First, offensive nuclear retaliatory forces must be modernized. This is necessary to reestablish and maintain the offensive balance in the near term and to create the strategic conditions that will permit the U.S. to pursue complementary actions in the areas of arms reduction negotiations and defensive research. In 1981, the U.S. embarked on a strategic modernization program aimed at reversing a long period of decline. This modernization program was specifically designed to preserve stable deterrence and, at the same time, to provide the incentives necessary to cause the Soviet Union to join the U.S. in negotiating significant reductions in the nuclear arsenals of both sides.

In addition to the U.S. strategic modernization program, NATO is modernizing its longer-range, intermediate-range nuclear forces (LRINF). Our British and French Allies also have underway important programs to improve their own national strategic nuclear retaliatory forces. The U.S. SDI research program does not negate the need for these U.S. and Allied programs. Rather, the SDI research program depends upon collective and national modernization efforts to maintain deterrence today as options are explored for possible future decisions on how we might enhance security and stability over the longer term.

Second, steps must be taken to provide future options for ensuring deterrence and stability over the long term and must be taken in a way that allows the U.S. both to counter the destabilizing growth of Soviet offensive forces and to channel longstanding Soviet propensities for defenses toward more stabilizing and mutually beneficial ends. The Strategic Defense Initiative is specifically aimed at achieving these goals. In the near term, the SDI program also responds directly to the ongoing and extensive Soviet anti-ballistic missile effort, including the existing Soviet deployments permitted under the ABM Treaty. The SDI research program provides a necessary and powerful deterrent to any near term Soviet decision to rapidly expand its anti-ballistic missile capability beyond that contemplated by the ABM Treaty. This, in itself, is a critical task. However, the overriding, long term importance of SDI is that it offers the possibility of reversing the dangerous military trends cited here by moving to a better, more stable basis for deterrence and by providing new and compelling incentives to the Soviet Union for seriously negotiating reductions in existing offensive nuclear arsenals.

In our investigation of the potential of advanced defensive systems, the U.S. seeks neither superiority nor unilateral advantage. Rather, if the promise of SDI technologies is proven,

the destabilizing characteristics of the current strategic environment can be rectified. And, in the process, deterrence will be strengthened significantly and placed on a foundation made more stable by reducing the role of ballistic missile weapons and by placing greater reliance on defenses that threaten no one.

Third, the U.S. will continue its strong commitment to arms control. Our near-term objective is a radical reduction in the power of offensive nuclear arms, as well as a safer relationship between nuclear offensive and defensive arms. We are even now looking forward to a period of transition to a more stable world, with greatly reduced levels of nuclear arms and an enhanced ability to deter war based upon the increasing contribution of nonnuclear defenses against offensive nuclear arms. A world free of the threat of military aggression and free of nuclear arms is an ultimate objective to which the U.S., the Soviet Union and all other nations can agree.

To support these goals, this country will continue to pursue vigorously the negotiation of equitable and verifiable agreements leading to significant reductions of existing nuclear arsenals. As it does so, it will continue to exercise flexibility concerning the mechanisms used to achieve reductions but will judge these mechanisms on their ability to enhance the security of the United States and its Allies, to improve strategic stability and to reduce the risk of war.

At the same time, the SDI program is being conducted in full compliance with the ABM Treaty. If the SDI program yields positive results, the U.S. will consult with its Allies about next steps. The United States would also consult and, as appropriate, negotiate with the Soviet Union, pursuant to the terms of the ABM Treaty which provide for such consultations, on how deterrence might be strengthened through the phased introduction of defensive systems into the force structures of both sides. This commitment does not mean that the United States will give

the Soviets any veto over a future U.S. decision on strategic defense. In anticipation of a possible future decision to deploy defenses, the U.S. has already begun the process of bilateral discussion with the Soviet Union in Geneva to address questions related to our objective of a jointly-managed transition integrating advanced defense into the forces of both sides.

D. THE ROLE OF THE STRATEGIC DEFENSE INITIATIVE

In summary, the President's Strategic Defense Initiative is an important effort to find a fundamental improvement in the long-term security of the U.S. and its Allies, and to provide a better response to the growing Soviet offensive and defensive threat. Recent advances in defensive technologies warrant a new evaluation of ballistic missile defense as a basis for a safer form of deterrence, more consistent with U.S. values. Possibilities for maintaining security by means of an enhanced ability to deter war through an increasing capability to defend against attack--rather than through sole dependence on the threat of nuclear retaliation--deserve, and are receiving, serious exploration.

CHAPTER IV

GOALS AND TECHNICAL OBJECTIVES

A. INTRODUCTION

This section describes the basic guidance under which the SDIO program is executed and the basic thrust of the resultant program. It discusses program goals, how these goals are being turned into program requirements, how these requirements can be met, and what the overall investment (funding) strategy is.

B. GOAL OF THE STRATEGIC DEFENSE INITIATIVE

The goal of the SDI is to conduct a program of vigorous research and technology development that may lead to strategic defense options that would eliminate the threat posed by ballistic missiles, and thereby;

- Support a better basis for deterring aggression;
- Strengthen strategic stability;
- Increase the security of the United States and its Allies.

The SDI seeks, therefore, to provide the technical knowledge required to support an informed decision in the early 1990s on whether or not to develop and deploy a defense of the U.S. and its Allies against ballistic missiles.

Program success in meeting its goal should be measured in its ability both to counter and discourage the Soviets from continuing the growth of their offensive forces and to channel longstanding Soviet propensities for defenses toward more stabilizing and mutually beneficial ends. Furthermore, the SDI program provides in the near term a definitive response to the Soviets' vigorous advanced anti-ballistic missile (ABM) research and development effort. Thus, the SDI could act as a powerful deterrent to any near term Soviet decision to expand rapidly its anti-ballistic missile system beyond that contemplated by the

ABM Treaty. Nonetheless, the overriding, long term importance of the SDI is that it offers the possibility of reversing dangerous Soviet military trends by moving to a better, more stable basis for deterrence. It could provide new and compelling incentives to the Soviet Union for serious negotiations on reductions in existing offensive nuclear arsenals.

There are no preconceived notions of what an effective defensive system against ballistic missiles should entail. A number of different concepts involving a wide range of technologies are, therefore, being examined. No single concept or technology has, as yet, been identified as the best or most appropriate.

C. THE BASIC REQUIREMENTS

A strategic defense system developed following the Strategic Defense Initiative Program, like any other major military system, would have to meet three specific standards.

Advanced defenses must be adequately survivable. They must not only maintain a sufficient degree of effectiveness to fulfill their mission even in the face of determined attacks on the defense, but also maintain stability by discouraging such attacks. Survivability means then that the defensive system must not be an appealing target for defense suppression attacks. The offense must be forced to pay a penalty if it attempts to negate the defense. This penalty should be sufficiently high in cost and/or uncertain in achieving the required outcome that such an attack would not be contemplated seriously. Additionally, the defense system must not have any "Achilles Heel." In the context of the SDI, survivability would be provided not only by specific technical "fixes" such as employing maneuver, sensor blinding and protective shielding materials, but also by such strategy and tactical measures as proliferation, deception, and self-defense. System survivability does not mean that each and every element of the system

need survive under all sets of circumstances; rather, the defensive force as a whole must be able to achieve its mission, despite any degradation in the capability of some of its components.

The second requirement is military effectiveness. A defense against ballistic missiles must be able to destroy a sufficient portion of an aggressor's attacking forces to deny him confidence that he can achieve his objectives. In doing so, the defense should have the potential to deny that aggressor the ability to destroy a militarily significant portion of the target base he wishes to attack. Furthermore, if a deployed defensive system is to have lasting value, technology and tactics must be available that would allow the system to evolve over an extended period, in order to counter any plausible "responsive" threat. Such a robust defense should have the effect of deterring a strong offensive response and enhancing stability.

Third, we will consider, in our evaluation of options generated by SDI research, the degree to which certain types of defensive systems, by their nature, encourage an adversary to overwhelm them with additional offensive capability while other systems can discourage such a counter effort. We seek defensive options--as with other military systems--that are able to maintain capability more easily than countermeasures could be taken to try to defeat them. This criterion is couched in terms of cost-effectiveness. However, it is much more than an economic concept.

D. IDENTIFYING DEFENSIVE OPTIONS

If the program is to support future decisions on defensive options, diverse efforts producing essential answers to critical issues must converge. Affordable ballistic missile defense architectures must be identified. The technical feasibility and readiness for development of survivable and cost-effective

systems capable of meeting and sustaining the performance needs of the architectures must be established. The doctrine and concepts of operation for applying the system elements of the preferred architectures must be formulated. Practical paths for implementing the strategy and deploying defenses in the context of foreign relations and arms control must be defined.

Since FY 1984, the SDIO has pursued efforts to identify the above requirements through the System Architecture Studies. The purpose of these studies is threefold. The first is to provide an initial definition and assessment of several alternative constructs of systems (architectures) that can detect, identify, discriminate, intercept and negate ballistic missiles in their boost, post-boost, midcourse and/or terminal phases. A second purpose is to provide a complete and balanced set of technological and functional requirements. This is accomplished by identifying the key trade-offs for sensors, weapons, command, control, communications, and supporting subsystems that can make the individual architecture viable and cost-effective. A third purpose is to define and prioritize critical technical issues that must be resolved before future decisions can be made on whether or not to implement a given defensive strategy.

The task of identifying reasonable defense architectures is an ongoing one. The evaluation and analysis of SDI technologies and designs must necessarily evolve as research progresses. Two important elements are integral to this task--(1) the analysis of potential responsive threats with which a proposed defense would have to cope and (2) the development of appropriate scenarios for use in simulations and evaluations.

The value of these studies, even at the generic level, should not be underestimated. The study of possible systems allows the SDIO to identify critical problem areas, develop measures of system effectiveness, and evolve new concepts. Without these steps the SDIO could not prioritize its investments. In addition, useful trade-off studies are performed

that, among other outputs, may allow the SDI to discover possible synergistic relationships between subsystems, major system elements and strategies.

The SDI Program will have a number of critical junctures. Clearly, the evolving description of emerging architectures will create several of these junctures. In the beginning simple constructs are being formulated and methodologies for evaluating systems concepts are being created. As more indepth steps are taken, the constructs will become more complex and the various trade-offs and assessments of performance will become more detailed. Ultimately, the most sophisticated architecture, together with its evaluative process, might involve the simulation of the entire defense in a battle engagement. The simulation would assist the SDIO in analyzing the outcome of a hypothetical battle. It would provide a measure of how well the constructs performed, as well as estimates of how much it would cost to develop, deploy and operate the particular defensive options selected.

E. ACHIEVING A TECHNICAL CAPABILITY

If the SDIO is to offer a high confidence basis for decisions to pursue one or more defensive options, the program must do several things. First, it must conduct a broad-based effort that expands and accelerates the progress of technology in a manner that supports the relevant architectures. Second, it must provide the architect with conceptual designs of the system elements. Such designs are needed if the architect is to evaluate the potential effectiveness of candidate ballistic missile defenses that could be assembled and deployed from those technologies. Third, it must provide a basis for showing how those defense options can be operated and maintained to do the job. It must do this research in activities that are conducted in accordance with applicable U.S. treaty obligations.

The SDIO must advance the technology in a logical and timely way in three experimental thrusts. First, the most mature technologies need to be validated in order to provide initial options for defense architectures that are affordable, survivable and effective. A decision in the future to proceed with a specific initial option would implement a defense against the threat the U.S. believes will be in place at least until early in the next century. Alternatively, the decision could be to reserve these options as a simple hedge against Soviet breakout and deployment of a defense against U.S. ballistic missiles. Second, the long term viability of future defensive options needs to be ensured by showing the feasibility and readiness of technologies to support more advanced defense options against an evolving and increasingly more capable threat based on the offensive technologies of the early twenty-first century. And third, research needs to be conducted that encourages innovation by the U.S. scientific community in reponse to the President's challenge to aid SDI in identifying and exploiting new approaches promising major gains in defense effectiveness.

F. THE BASIC PROGRAM BUILDING BLOCKS

To meet the requirements of an early 1990s decision milestone, the SDIO has established a program that has as its building blocks the following elements:

- A technology base program,
- Major experiments which include:
  - Technology integration experiments, and
  - Demonstration-of-capabilities projects.

Well over 50 percent of the scientific work in the SDIO falls into the technology base category. It encompasses the large number of individual "small science" efforts, that is, programs with small to modest funding. The work is comprised of both basic and applied research. Some of this work involves

relatively straightforward extensions of existing technology; it also includes high risk, but high payoff efforts. The technology base program is intended to foster the birth of many innovative ideas. The programmatic objective is to provide the framework of knowledge needed to pursue integrated experiments and to build opportunities for program growth, particularly in those disciplines that might have far reaching impact.

In order to focus and integrate this evolving information, key projects have been chosen that are designed to provide the needed proof-of-feasbility of the critical elements of an SDI system. Examples of efforts that fall into this category are: scaling experiments for a laser device, development of new infrared (IR) sensor materials, study of lightweight shielding material to protect both boosters and spacecraft from laser attack, research into large structures to be used in space, and creation of advanced software engineering techniques to provide improved feasibility and testability.

Proof-of-feasibility experiments tend to be moderately expensive and are driven (or selected to be driven) by time urgency. They are intended to show rapidly the feasibility of a key technology with high payoffs. These efforts often follow the concept of pursuing parallel technology paths when possible in order to lower the risk of these ambitious projects. The emphasis in these projects is on the early resolution of a major issue that, if resolved favorably, can have a substantial impact on the success of the long term SDI goal. Examples of such projects are: the integration of a high power free electron laser and beam director, a study of a space-based neutral particle beam accelerator and sensor package, a booster tracking and weapon platform pointing experiment, and an integrated study of kinetic energy intercept of a reentry vehicle in outer space similar to the Homing Overlay Experiment.

Experiments to prove capabilities are the next step beyond showing technological feasibility and the last phase preceeding full scale development. Examples of these projects are the exercise of test beds to demonstrate capabilities in tracking missiles in the boost phase, discriminating decoys from warheads, and hit-to-kill exoatmospheric and endoatmospheric intercept. These experiments involve technology that has already been demonstrated as feasible and must now be integrated with other subsystem requirements. These projects are characterized by emphasis on integration of constituent elements and the performance of functional tests. They will bring feasible technology into engineering proof-of-principle. Experiments at this phase give some understanding of what are often called the "unknown-unknowns" that must be dealt with before any reasonable thought can be given to development and then deployment. These experiments are also expensive and time consuming. On the other hand, integration and further testing offer ways of avoiding more costly mistakes that often occur due to premature decisions to develop more complex integrated concepts. If the technology base is forced into an excessively lean posture, then the technical risk for these projects may become unacceptably high, that is, there will be limited flexibility with which to perform side-steps to assure ultimate project success. These programs can and should rely on the technology base program for help when the inevitable unknowns become apparent. These experiments are quite sensitive to and driven by fiscal and time constraints. These integration projects and functional tests have been structured to be carried out in conformity with the restrictive interpretation of the ABM Treaty.

G. THE INVESTMENT STRATEGY

Given the three basic areas of the SDI program, how are priorities being set? The establishment of a viable investment strategy for the SDIO has been of major importance since priorities have undergone constant reevaluation due to the large budget reductions imposed by Congress.

The current investment strategy is to:

- Protect the technology base;
- Increase the emphasis on proof-of-feasibility experiments with increased investment in the high risk-high payoff approaches; and,
- Decrease the number and scope of capability demonstration projects.

The possible drawback of this approach is that the technology base program could turn into what has been termed in other cases "technological filibustering", that is, rejecting the "good enough" in search for something "better". The positive view, of course, is that SDIO would develop a better end product, one that gives the U.S. the kind of leverage necessary to make defenses work reliably, robustly, and at a reasonable cost. There will admittedly need to be a constant vigil stood over the priorities set between the technology base and feasibility experiments. The program can neither afford to pursue "science for the sake of science" nor to proceed with risky experiments having an inadequate technology base.

The following examples illustrate the above points of new philosophy. The demonstration-of-capabilities activities have been intentionally reconfigured into an experimental mode emphasizing key technology issues rather than the integration aspects:

- Space Surveillance Tracking System (SSTS),
- High Endoatmospheric Defense Interceptor (HEDI),
- Exoatmospheric Reentry Vehicle Interceptor Subsystem (ERIS),
- Terminal Imaging Radar (TIR), and
- Integration Test and Demonstration Project (ITD).

On the other hand, a number of areas have been selected for greater emphasis in achieving proof-of-feasibility at an early date. They are:

- Ground-based free electron laser integration experiment,
- Space-based neutral particle beam integration experiment,
- Space-based kinetic energy technology experiments, and
- A set of space pointing and tracking experiments.

These upgraded projects are a natural outgrowth of SDI emphasis on critical path programs oriented toward resolving the key issues needed for the technical and programmatic inputs to the decision in the early 1990s. These experiments will also provide a timely, visible and understandable set of milestones with which to measure program progress and accomplishment. The key to the success of this approach is to incorporate multiple paths to satisfy key needs for successful defense architectures and thus avoid single point failures. The reduction of the requested budget levels by Congress has not, as yet, had the effect of slowing project schedules. It has had the effect, however, of not allowing the SDI to fund the alternative or fall-back technologies at a separate level to minimize program risk. The best example of this is in the Directed Energy Program where the technology is least mature and the number of potentially promising concepts large--only a few technologies can be emphasized.

H. THE BASIC PROGRAM STRUCTURE

With this priority-setting philosophy in hand, the program is logically divided into three basic elements. There are the "hardware" technology programs such as Directed Energy Weapons (DEW); Kinetic Energy Weapons (KEW); Surveillance, Acquisition,

Tracking and Kill Assessment (SATKA); and Survivability, Lethality and Key Technologies (SLKT). There are the "software" programs such as Systems Analysis and Battle Management (SA/BM) and Countermeasures work. There are ancillary areas that address the threat and threat projections, in addition to an activity to stimulate innovative science and technology.

The priority decisions that affect the technical programs are driven by systems requirements including possible Soviet responsive threats. These programs are described in Chapter VII, "The Technical Challenge". The analytical programs such as the "horse race" architecture studies and the Red Team/Blue Team countermeasures work should be viewed differently from the "hard" programs. These programs engage in studies to uncover problems and allow for definition of the critical issues. Such areas give the program general guidance and, when properly coupled through appropriate feed-back loops to and from the technical programs, provide a strong focus for the overall SDI program. These activities basically define the questions that the hardware programs must resolve and thus define the priorities in the face of limited resources.

In the area of countermeasures, the SDIO has set up Red/Blue technical teams to provide interchange on SDI systems and possible countermeasures and counter-countermeasures, but we are attempting also to mimic the higher level Soviet Government response through the establishment of a mock "Politburo." This approach, hopefully, will provide some semblance of a "holistic" interpretation of possible Soviet responses to a defense deployment. Results in the form of predictions are yet to come forth, but will no doubt prove interesting, perhaps controversial, and clarifying.

I. THE TECHNICAL DEVELOPMENT PACE

A notional schedule for research and possible development and deployment would be comprised of four phases:

- The research-oriented program, begun by the President in his 1983 Initiative, would run into the early 1990s when a decision could be made by a future President and Congress on whether or not to enter into full-scale system engineering development. This activity will be conducted within the constraints of our current treaty commitments.

- The systems development or full-scale development phase could begin as early as the 1990s.

- A transition phase would be a period of incremental, sequential deployment of defensive systems. This phase could be designed so that each added increment would further enhance deterrence and reduce the risk of nuclear war. Preferably, this transition would be jointly managed by the U.S. and the Soviet Union, although such Soviet cooperation would not be a prerequisite.

- The final phase would be a period of time during which deployment of highly effective, multilayered defensive systems would be completed and during which offensive ballistic missile force levels could be brought to a negotiated nadir, and hopefully, eliminated.

Presently in its first phase, the SDI program is focused to bring defense options to the point where U.S. leaders, after consultation with the Allies, could make decisions on whether or not to proceed. The technology needed to proceed with confidence along a development path should be sufficiently in hand. In other words, the majority of effort needed from that point on should be engineering in nature rather than experimental. The mission and performance envelopes should be adequately defined. The best technical approach should have been selected by means

of a thorough trade off analysis. This involves the identification of alternatives, examination of their feasibility, and comparison in terms of performance, cost, technical risk and development time. Last, cost and schedule estimates should be credible and acceptable. For these conditions to be present, concept formulation and technical feasibility studies would have to be favorably completed so that questions regarding prospects for achieving the desired goals and potential pay offs could be answered with reasonable certainty.

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CHAPTER V

KEY FUNCTIONS OF A DEFENSE AGAINST BALLISTIC MISSILES

A. OVERVIEW OF THE DEFENSE ENVIRONMENT

The critical requirement imposed on an effective ballistic missile defense system is the need to achieve low leakage of nuclear warheads when threatened by large, sophisticated attacks as well as attacks on the defense system itself. A strategic defense capable of engaging appropriate targets all along the ballistic missile flight path must perform certain key functions:

- Detection: The rapid and reliable warning of an attack and the readying of defense assets to intercept appropriate targets. This includes the capability to provide full-time surveillance of ballistic missile launch areas (potentially worldwide) to detect an attack and identify its location; characterize the composition and intensity of the attack; determine the probable targeted areas for confident initiation of the battle; and provide track data to aid the defensive systems in acquiring the targets.

- Tracking, Identification/Discrimination: The precise and enduring "birth-to-death" tracking of targets and other objects of interest associated with a ballistic missile attack. This also includes the effective discrimination of penetration aids and decoys; timely kill assessment; and efficient battle management, data processing and communications capabilities to coordinate the defensive battle and optimize the use of defense assets.

- Interception and Destruction: The rapid, effective and discernible kill of ballistic missile boosters, post-boost vehicles, and reentry vehicles along the

entire flight path of the ballistic missile. The defense must be capable of stopping an attack ranging from a single missile to massive, simultaneous launch that may require 10 or more kills per second by the defensive weapons in the battle. Defending against an attack while the ballistic missiles are still at the beginning of their flight path (the boost and post-boost phases) is attractive, for it maximizes the number of reentry vehicles killed and minimizes the deployment of decoys and penetration aids.

- Battle Management, Coordination: The effective manipulation of information about the defensive battle, the generation of displays to inform the defense commander, and the transmission of his decisions to the defense elements.

There are two basic approaches in designing a system to perform the necessary functions and achieve the goal of very low leakage. The first involves the use of extremely high performance system elements, and the second relies on redundant combinations of system elements performing at more modest levels. It is generally accepted that an efficient defense against a high level of threat is a layered defense requiring all of the above capabilities. For example, with a single layer system, the failure of any function may result in overall failure. The defensive system would only be as strong as its weakest link. A target which is not detected would not be intercepted and thus would leak through the single defensive layer. Similarly, a reentry vehicle that is incorrectly classified as a decoy would not be intercepted. Clearly, very capable system elements would be required for a high confidence single layer ballistic missile defense.

The second, and preferred approach recognizes that near-perfect element performance is unlikely and, even if possible, might be too expensive. This approach envisions a multi-tiered defense with each tier capable of performing independently the basic functions of threat detection, tracking, identification, pointing and/or weapon guidance, destruction, kill assessment, coordination and self defense. If an element within a single tier fails, the target leaks through to the next tier where the defense has another chance to detect and intercept the target. Three independent tiers, each of which allows 10 percent leakage, for an overall leakage of 0.1 percent, are likely to be less costly than a single tier that has the same total leakage since the performance requirements for each tier can be substantially lower than those required for a stand-alone tier.

A typical trajectory of current ballistic missiles can be divided into four phases:

- A boost phase when the missile's engines are burning and offering intense, highly specific, observables;

- A post-boost phase, also referred to as the bus deployment phase, during which multiple reentry vehicles (RVs) and penetration aids are being released from a post-boost vehicle (PBV);

- A midcourse phase during which RVs and penetration aids travel on ballistic trajectories above the atmosphere; and

- A terminal phase during which RV trajectories and signatures are affected by atmospheric drag.

Short-range submarine-launched ballistic missile (SLBM) and intermediate-range ballistic missile (IRBM) trajectories have similar boost and terminal phases but, in most cases, have less extensive busing and midcourse phases.

For convenience, we have grouped the functions into three headings in the discussion which follows--surveillance (detection, initial identification), acquisition (tracking, identification/association/discrimination, kill assessment, coordination), and intercept (pointing/guidance, destruction, self defense).

Boost and Post-Boost Phases. The ability to respond effectively to an unconstrained threat is highly dependent on the capability of a boost-phase intercept system. For every booster payload killed, the number of objects to be killed by the remaining elements of a layered defense system is reduced substantially. Such kills also disrupt the highly structured attacks that stress terminal systems.

A boost phase defense system is currently constrained by extremely short engagement times and potentially large number of targets. These constraints create a requirement for a surveillance and battle management system with weapons release authority based on predetermined, technically measurable conditions for engagement. They dictate a weapons system that can deliver enough energy to each target in the limited available engagement time to ensure booster kill.

The post-boost phase is potentially rich in information that can be used for discrimination. As this phase of flight proceeds, the leverage decreases as decoys and RVs are deployed. On the other hand, the post-boost phase offers additional time for it to intercept boost phase weapons and may be the predominant phase accessible after certain Soviet boost phase responses.

Midcourse Phase. Intercept outside the atmosphere forces the defense to cope with decoys designed to deceive interceptors and exhaust the force. Fortunately, available engagement times are longer (approximately 1500 seconds) than in other phases.

This freedom from tight timelines in the boost (150 to 300 seconds), post-boost (300 to 500 seconds), or terminal (20 to 50 seconds) phases strongly argues that a midcourse intercept system is an important element in a comprehensive defensive capability. The midcourse system must, however, provide both early filtering of non-threat objects and continuing attrition of threat objects if the defense is to minimize the pressure on the terminal system. Failure to start the defense before midcourse could result in a tenfold to several hundredfold increase in objects in the threat cloud from multiple independently targeted reentry vehicles (MIRVs), decoys, chaff, and junk.

Terminal Phase. The defended area of a terminal-defense interceptor is determined by how fast it can fly and how early it can be launched. Since terminal-defense interceptors fly within the atmosphere, their average velocity is limited. How early they can be launched depends on the requirements for discrimination of the target from penetration aids and accompanying junk and designation to the interceptor. A requirement for independent discrimination delays launch of the interceptor and reduces the "footprint" or defended area. Moreover, since the terminal defense of a large area requires many interceptor launch sites, the defense is vulnerable to saturation and preferential offensive tactics. Such structured, preferential attacks lead to a desire to complement the terminal defense with area defenses that intercept at long ranges and provide wider defense footprints. Such a complement is found in a system for exoatmospheric intercepts in the midcourse phase.

Structured, preferential attacks make it necessary to complement the terminal defense with area defenses that intercept at long ranges and provide wider defense footprints/coverage. Such a complement is found in a system for exoatmospheric intercepts in the midcourse phase.

The phenomenology and required technology for each of these phases of a ballistic missile trajectory are different. While there is considerable technical overlap of systems between phases, it is useful to separate system concepts into these phases for the purpose of discussing top-level performance goals, identifying broad technical approaches to achieve those goals, and identifying key issues to be resolved. The remainder of this chapter discusses these topics in the context of boost, post-boost, midcourse, and terminal defense systems.*

B. BOOST PHASE (BOOST IGNITION OF POST-BOOST VEHICLE OPERATIONS)

Functional Needs

Functional needs and performance goals for defensive actions in boost phase operations are highly sensitive. They are particularly sensitive to two assumptions concerning the number of targets to be engaged as a function of time and/or assumed target vulnerability. The first assumption encompasses the performance of the surveillance and target acquisition system, the battle management and data processing system, and the fire-control or weapon-guidance sensors. The second assumption (target vulnerability) has a major impact on the performance of the weapon. Both dictate the number of weapons required. Survival and endurance of all boost phase systems are crucial.

- Surveillance. The requirement to detect launches and associate target signatures with specific booster tracks is fundamental. High sensor resolution is needed. Upon detection, the system must be capable of handling many individual targets.

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* These discussions establish the basis for investment strategy and technology development required to realize defense-in-depth concepts.

- Acquisition. When individual booster tracks are identified, the Battle Management and Command, Control and Communications (BM/C^3) systems allocate individual targets or groups of targets to a specific weapon or weapon platform. Sensors supporting that platform must then find and track the relatively cool rocket body in the presence of a hot exhaust plume. The pointing accuracy for this function can vary considerably depending largely on the type weapon that sensors are supporting.

- Intercept. Directed energy kill mechanisms must, in general, deliver from a few to tens of megajoules of energy to the booster or post-boost vehicle. Some weapons concepts attack targets serially using available battle time to move from target to target. In such systems, retarget time must be limited from a few seconds to a fraction of a second in order to achieve required high kill rates. Other concepts engage targets in parallel and do not require rapid retargeting. Some concepts involve physically hitting the target with a homing warhead that must be precisely guided. Finally, one must sense, in near real-time, whatever characteristic changes occur in the target that indicate that it has been successfully engaged.

Candidate Technologies

The candidate technologies to perform these boost-phase intercept functions are:

- Surveillance. There is sufficient confidence in surveillance technologies that a space-based sensor system can be developed to support boost-phase intercept requirements.

- <u>Intercept</u>. Generic weapons concepts applicable to boost phase kill include:
  - Thermal kill lasers--burn through of the booster skin resulting in breakup of booster--include continuous wave (CW) and repetitively-pulsed beams as wavelengths from IR to ultra-violet (UV).
  - In-depth energy deposition by particle beams--soft kill of electronics, detonation of high explosives and melting of components and structures--include neutral and, possibly, charged particles.
  - Kinetic energy impact kill using homing projectiles propelled by chemical rockets or an electromagnetic gun.

Since a responsive threat might achieve boost-phase termination in the atmosphere, the need to propagate the kill energy through the atmosphere may limit the applicability of some of the candidates.

C. POST-BOOST PHASE

<u>Functional Needs</u>

The post-boost vehicle's dispensing phase begins at the end of booster burn and ends for each reentry vehicle or penetration aid as it leaves the PBV or "bus". Accordingly, acquisition, tracking and discrimination between RVs and decoys and debris are key functions that begin in this phase and continue into the midcourse phase. Since the target is the PBV, the target engagement and energy delivery functions are similar to those for boost phase.

- <u>Surveillance</u>. In the post-boost phase, discriminating RVs from other objects is a key functional need.

- Acquisition. The functional needs are essentially the same as for boost phase with some differences.

- Intercept. One would probably use boost phase kill mechanisms in the PBV phase, although substantial differences in the vulnerability of PBVs and boosters are expected.

Candidate Technologies

Candidate technologies for performing the post-boost phase functions include:

- Surveillance. Discrimination may be by multi-spectral sensors of many different wavelengths with a variety of techniques and forming one of a number of platforms.

- Acquisition. The boost phase candidates are appropriate candidates for this phase.

- Intercept. The boost phase candidates are also candidates for the PBV phase.

D. MIDCOURSE PHASE

Functional Needs

Midcourse defense involves detecting and destroying RVs after their deployment from a PBV and prior to atmospheric reentry at altitudes of about 100 km. Acquisition, tracking and discrimination are the key functions in continuing defense against ballistic missiles during this phase. Assuming discrimination is possible, multiple engagement opportunities are available over the relatively long time of flight, approximately 1500 seconds.

- Surveillance. An autonomous midcourse surveillance function requires sensors that detect all threatening objects in the midcourse regime and rapidly

reject (bulk filter) lightweight decoys and debris that exist in large quantities. Credible objects (RVs and heavy decoys) must be precisely tracked and the RVs discriminated from heavy decoys. RV position and trajectory data of adequate accuracy for firing kill devices must be provided and kill assessment performed. As in the PBV phase, groups of objects must be classified, track files established and state vectors handed over.

- Acquisition. Precision tracking of designated objects is required to provide the position of the target needed for intercept. This consists of trajectory predictions accurate for battle management and handover to a midcourse hit-to-kill interceptor. In addition, position accuracy is needed for handover to acquisition, tracking, and pointing subsystems of directed energy weapons.

- Intercept. Since the targets (RVs) must be protected against the heat and forces of reentry, they are inherently hard to thermal and impulse kill mechanisms. For high confidence, kill mechanisms must deliver a few tens of megajoules of energy to the target. The long duration of the midcourse trajectory offers opportunities for multiple engagements even with modest interceptor velocities.

Candidate Technologies

Candidate technologies for performing the midcourse functions include:

- Surveillance. Midcourse surveillance needs may be provided by space-based platforms carrying multiple sensors for multiple functions. These sensor suites would be supported by communication, data-processing equipment, and signal processing.

- Acquisition. As in boost phase, tracking and pointing for designation can be based on technologies now under development.

- Intercept. The long time line available for midcourse intercept substantially reduces the relative payoff for extremely high velocity delivery of kill energies. Also, the geometry of the problem provides a wide variety of locations for basing of weapons. Forward basing midcourse interceptors would also provide engagement opportunities just after the reentry vehicles reach apogee. Space-based kill vehicles would be available globally to perform functions such as defense of Europe against intermediate-range missiles. Also, high performance directed energy weapons may have considerable potential during midcourse phase.

E. TERMINAL PHASE

Functional Needs

A terminal defense concept must protect urban/industrial and military targets against offensive weapons which have not been killed in the preceding phases of the missile's trajectory.

The driving requirements for the terminal tier of defense are a survivable and affordable system that can defend the entire United States. Defense of soft targets demands a keep-out altitude above which all RVs must be killed to prevent damage to soft targets. The need to provide keep-out over the entire United States requires that the defense elements have large footprints, that is, the area defended must be large in order to limit the number of elements needed for full coverage.

- Surveillance. The basic functions of the surveillance supporting the terminal-phase system are to

acquire and sort all objects that have leaked through early defense layers and to identify the remaining RVs. Such actions will be based, where possible, on handovers from the midcourse engagements. Although only a small fraction of the lethal RVs will reach the terminal tier intact, junk from the entire attack may arrive over the United States.

- Acquisition. When a threatening object is identified, a homing interceptor must acquire its target and maneuver to kill it. Homing accuracies depend on the warhead used.

- Intercept. For targets that require the interceptor to fly a considerable distance, the intercept will take place near the keep-out altitude. The high velocity of the interceptor permits it to have a relatively large footprint (defended area).

Candidate Technologies

Both target acquisition and tracking and interceptor/kill vehicle requirements have been analyzed extensively. The candidate technologies emerging from such studies are:

- Surveillance. A well-defined concept uses an airborne optical sensor (AOS) that detects arriving reentry bodies and initiates tracking on those above an established threshold. The platform can carry enough sensors to detect and track, redundantly, all credible objects.

F. SPECIAL CONSIDERATIONS--SHORTER RANGE BALLISTIC MISSILES

Slower reentry speeds, greater angle of reentry, fewer penetration aids, plus potentially low apogees of SLBMs and

IRBMs pose a different set of defense problems. It is possible these factors may provide offsetting advantages in defending against shorter range systems. The low apogees associated with some of the shorter range classes of IRBMs or with depressed SLBMs make midcourse intercept difficult. However, the limited geographical area threatened by IRBMs would enhance the effectiveness of the terminal defense layer.

Defense against tactical ballistic missiles (TBM) also requires special consideration. However, the elements of the terminal tier of a defense system against longer range missiles could be adapted to anti-tactical ballistic missile (ATBM) systems.

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CHAPTER VI

CONSIDERATIONS IN DEFINING DEFENSE ARCHITECTURES

A. THE DEFINITION PROCESS

To answer some basic questions concerning the SDI it is necessary to understand the technical requirements, define the technology issues and identify the systems issues which need resolution through either ground test or simulation. To shed light on these issues it is necessary to perform systems concepts studies. Such studies are trade and sensitivity investigations across a number of system design options involving architectures of the components of ballistic missile defenses--the surveillance, weapons, C^3, etc. In studying the purpose of a system, one naturally has to investigate the missions to be satisfied, which in turn, are a function of the threats confronting it and the military strategy within which the system is operating. The architecture study, which is in the preliminary stage, and the individual conceptual designs of the various components of the system architecture developed in the other Program Elements attempt to deal with these questions.

The systems analysis process starts with the definition of a defense system architecture (Figure VI.1). This establishes the context within which various technologies may be integrated into a system that will achieve the SDI mission. Once a candidate defense system architecture is defined, the performance requirements of the defense subsystems may be established and through that process the SDI program requirements for developing those technologies may be determined. In establishing the defense subsystem performance requirements, various tactics and strategies on the part of the offense and defense must be evaluated. On the offensive side, special consideration must be given to defense suppression attacks, defense avoidance, etc. On the defensive side, emphasis must be placed on configuring the candidate defensive subsystems in a manner to optimize the overall performance of the defense.

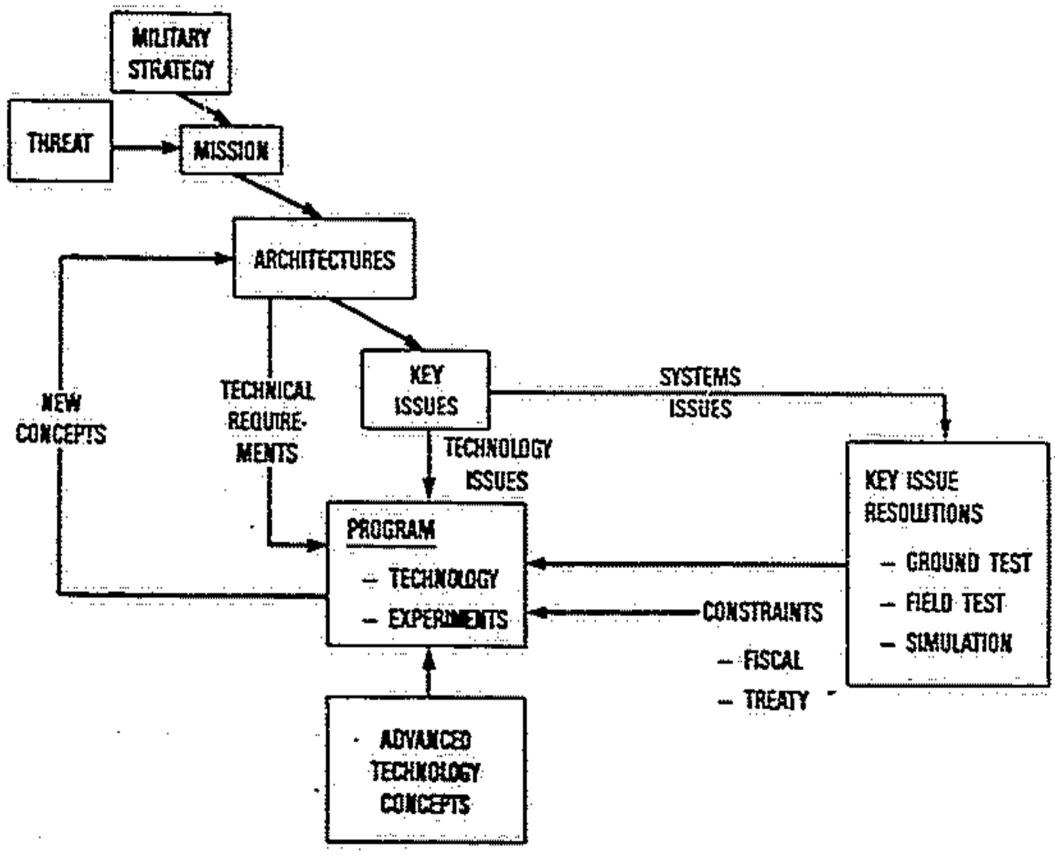

Figure VI.1. Systems Analysis and Program Requirements Process

The analysis of the effectiveness of a candidate defense architecture leads to a definition of the technical requirements of the subsystems comprising the architecture and the identification of key issues that must be resolved to make that architecture viable. These key issues may be technology related or systems related, and their resolution is accomplished by some combination of ground test, field test, and simulation. The SDI, which combines research in relevant technology areas with selected experiments, must be structured to satisfy the technical performance requirements established by the architectures and resolve the identified key issues. This must be achieved within the programmatic, fiscal, and treaty constraints, and on a schedule compatible with a decision in the early 1990s whether to proceed to system development.

An important objective of the SDI is the pursuit of several candidate architecture options and the promotion of advanced technology concepts which could form the basis for new architectural options.

B. ARCHITECTURE CLASSES

This section describes some conceptual examples of architecture options to engage a ballistic missile during the boost, post-boost, midcourse and terminal phases of its trajectory. Two figures describe a nonnuclear ground- and space-based architecture; one demonstrates the use of a DEW discriminator, the other shows the addition of a directed energy weapon to the system. A ground-based KEW architecture is displayed in the third figure. A fourth figure presents a defense architecture to counter shorter-range threats. Discussion accompanies each figure.

C. EXAMPLE ARCHITECTURES

Nonnuclear Ground- and Space-Based Architecture

Figure VI.2 displays this architecture class which uses a space-based directed energy weapon (DEW) as a discriminator.

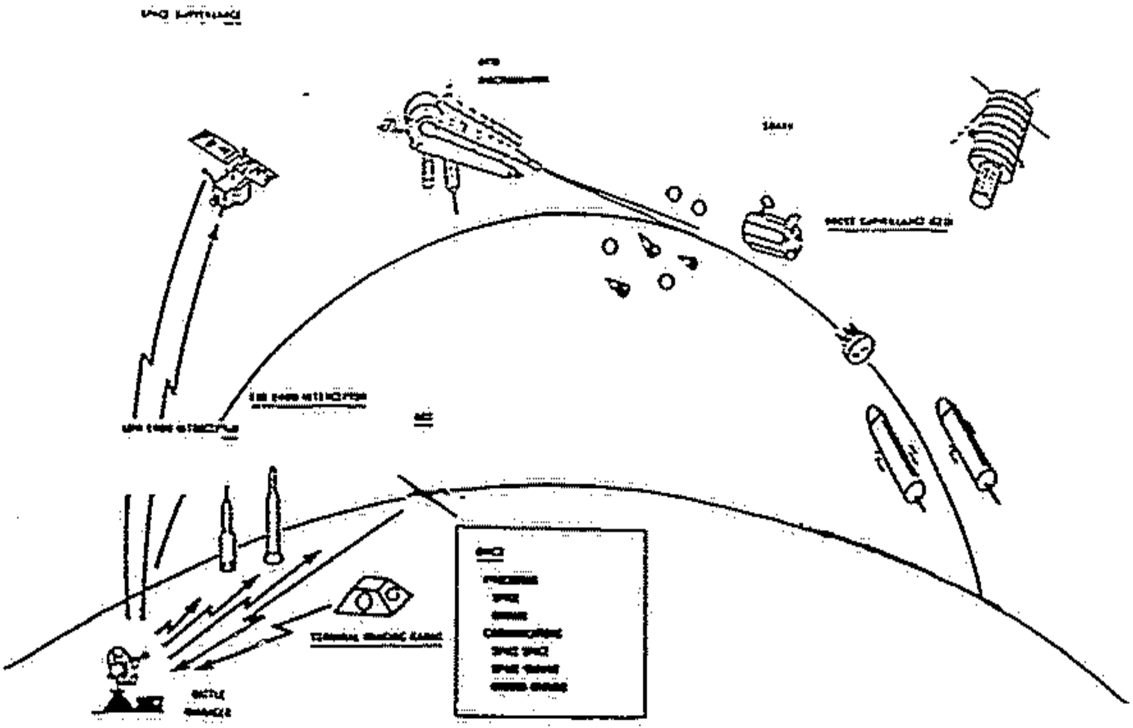

Figure VI.2. An Example of a Nonnuclear Ground- and Space-Based Architecture (DEW Discrimination)

In this representative architecture, system alert is provided by one or more of a small number of boost-surveillance satellites. These satellites provide initial boost track if they are adequately protected against defense suppression attacks. Otherwise, they serve only an alerting role. A second set of satellites for space surveillance provide essential acquisition, tracking, and discrimination functions. These satellites must therefore be located, proliferated and defended to have their function survive a defense suppression attack.

Space-based kinetic kill vehicles, SBKKVs, (shown in Figure VI.3) engage the threat in either the boost, post-boost or midcourse phases of its trajectory. The kill vehicles are required to attack essentially all boosters or reentry vehicles (RVs) in midcourse if the RVs are unaccompanied by large numbers of penetration aids. The kill vehicles are dispersed over many platforms to counter defense suppression attacks. SBKKVs must defend themselves as well as other space assets from potential space-based threats.

In addition to defense suppression, a responsive offense can shorten the burntime of the ballistic missile booster; depress the trajectory to diminish the effectiveness of intercept in the boost or post-boost phases; and proliferate penetration aids to overwhelm the defense during the midcourse phase. The desirability of achieving high confidence in effective midcourse discrimination promotes the consideration of using directed energy weapons (or even kinetic means) to modify the behavior or signature of the penetration aids in order to identify them. The neutral particle beam and various lasers are also promising devices to engage in interactive or intrusive discrimination.

To assure low leakages, a terminal defense must effectively engage the RVs which leak through the space-based and midcourse engagement regimes. Two types of ground-based interceptors are envisioned for this purpose. One operates against

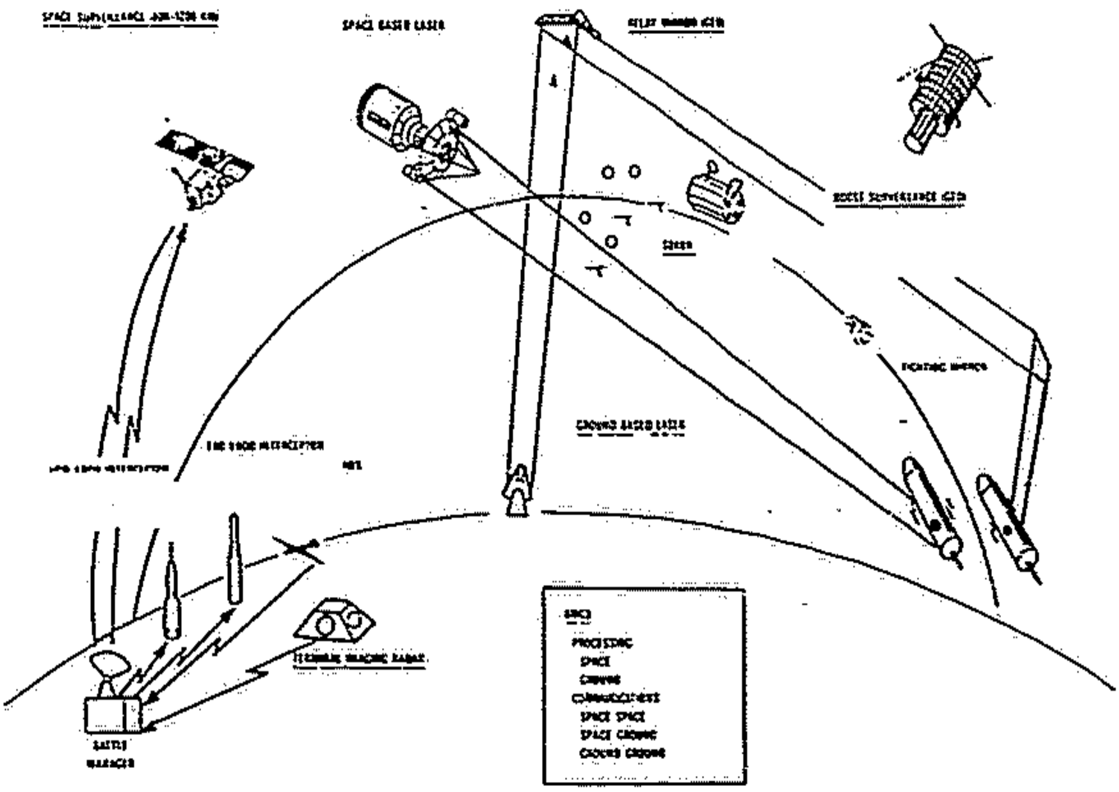

Figure VI.3. An Example of a Nonnuclear Ground- and Space-Based Architect.re (Weapon DEW)

the threat in the exoatmospheric and high endoatmospheric regimes. The other operates in the mid-to-lower endoatmospheric regime. Airborne sensor platforms are used in conjunction with this aspect of terminal defense.

As shown in Figure VI.3, the boost phase effectiveness of a near-term space-based kinetic kill vehicle defense system may be augmented by adding directed energy weapons to the architectures. These are necessary in offensive responses when the engagement time available during the boost phase is reduced. Among directed energy weapons, some high energy lasers are able to counter threats before they reach space, thereby increasing engagement time. Two alternatives are shown: a space-based laser and a ground-based laser using space-based relay and fighting mirrors. In either alternative, the number of space-based elements is likely to be small since these DEW weapons have very high kill rates. This offers the offense an option to concentrate an attack on these assets in an effort to destroy the boost phase defense capability of the system. Use of a kinetic energy-directed energy weapon against the offense offers a strong deterrent. To destroy this defense, the offense must pay a very high price.

The lasers required to achieve booster and post-boost vehicle (PBV) kill have substantially higher performance levels than the levels required for performing the midcourse discrimination function described previously.

Ground-Based Weapons Architecture

The second architecture class of interest is ground-based assets. It consists largely of midcourse and terminal kinetic energy weapons with a small number of surveillance satellites (Figure VI.4). The satellites are used to provide early warning of offensive missiles detected in their boost phase. This class is being examined because it relies on active defense elements not deployed in space and could be effective in cases where the offense is limited.

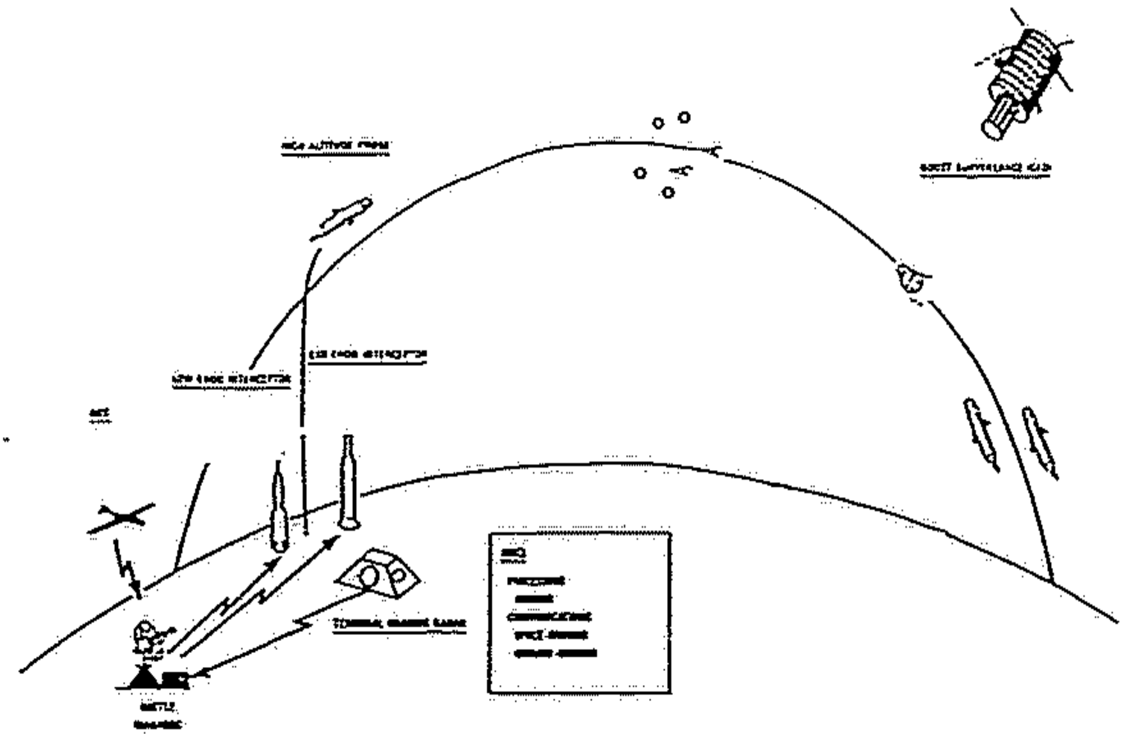

Figure VI.4. Ground-Based KEW Architecture

The midcourse tier of this class employs high altitude probes to initiate exoatmospheric engagements at long range. The remaining components and terminal tier functions are similar to the first architecture class although they must be deployed in larger quantities to compensate for the large number of engagements needed in the absence of a boost phase intercept capability.

Recent technological developments show that directed energy weapons devices may add performance growth potential to a ground-based architecture by adding a boost-phase intercept capability. DEW devices may also increase the midcourse intercept capability. The possibility also exists to build DEW devices of considerably increased brightness.

Pop-up DEW may assist in greatly alleviating the midcourse problem through effective discrimination of penetration aids in their midcourse. Providing this level of assistance, this class could become a much more viable candidate in moderate threat levels.

Hypervelocity particles also have promise as part of a strategic defense in this class. Particles traveling at such velocities may be able to attack individual missiles in their boost and post-boost phases.

Defense Architecture to Counter Shorter-Range Threats

The third architecture class addresses the Allied defense concept. The U.S. and its Allies are protected by existing and supplementary new deployments which provide coverage against shorter range threats. Figure VI.5 demonstrates the defense architecture to counter such shorter range threats. The nature of the threat to all U.S. Allies is being considered. Unique architectural requirements for allied defense are determined by three factors: different threat characteristics, targets implicit in the mission(s) and the target value and geographic distributions.

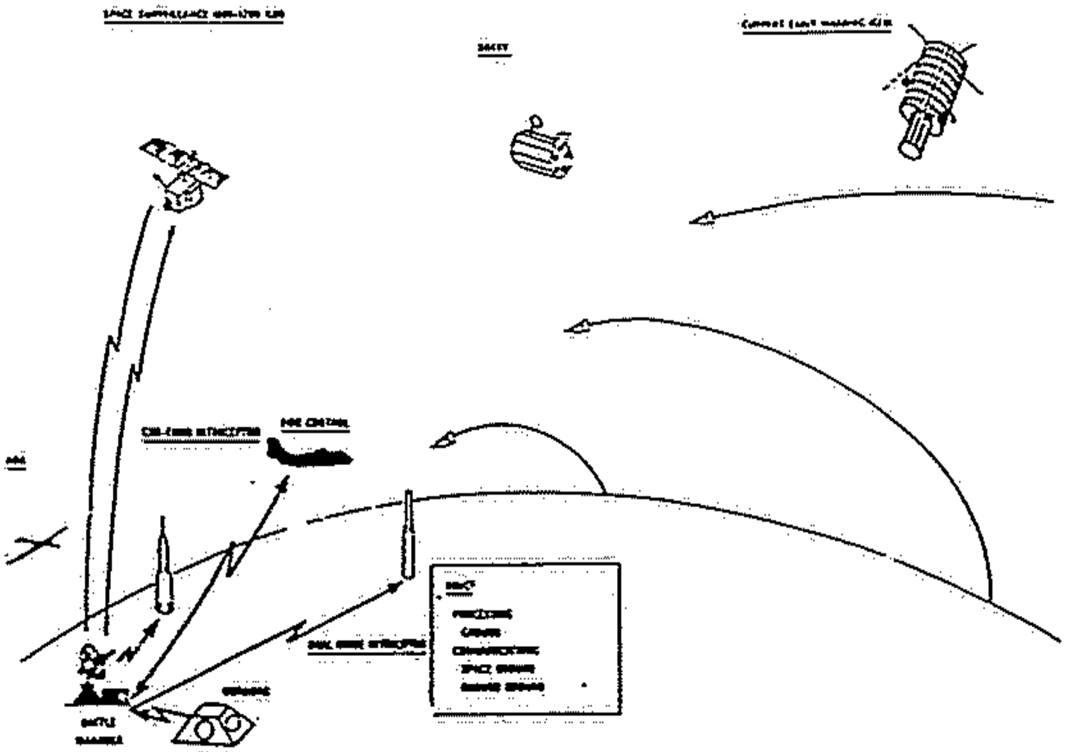

Figure VI.5. Defense Architecture to Counter Shorter-Range Threats

Space-based early warning and surveillance systems play a key role in timely warning, track and support for the defense against most shorter range ballistic missiles. Because the threat is much smaller, space-based kinetic kill weapons deployed for conus defense can be made available as needed, although the details of their use are scenario dependent.

Short range threats with reduced engagement time require additional fast acting tiers on the part of ground-based defense to achieve low leakage rates. One of these tiers uses long-range exoatmospheric and endoatmospheric interceptors. The other is deployed near the forward edge of the defended regions which are exposed to shorter range threats. A possible dual-mode interceptor capable of engaging these threats, as well as air-breathing cruise missile threats, is shown in Figure VI.5. An airborne fire-control component is required to maximize the line-of-sight coverage, engagement performance and kill assessment for these engagements.

D. KEY OBSERVATIONS

General

A defense system designed to operate in the late mid-course through terminal regions can only accommodate a limited number of independent tiers. As a result, the ability to achieve low leakage with such a defense is limited. This may be adequate for limited threats. However, it does not provide the very low leakage required for significant protection of U.S. and Allied nations from particularly large threats.

Discrimination

Good exoatmospheric discrimination is essential to effective midcourse defenses, especially when large numbers of light decoys are involved. Reentry vehicles with penetration aids can make discrimination difficult and uncertain for the defense.

A midcourse defense with good discrimination can operate synergistically with boost phase defense, i.e., the benefit an attacker gains from fast-burn missiles is offset. Fast-burn boosters have fewer RVs and penetration aids. Inexpensive midcourse interceptors could be proliferated to offset poor discrimination performance against heavy precision decoys.

Active laser or radar sensors that measure body dynamics, size, and shape of objects during and after deployment appear to offer the best <u>sensor-based</u> solution for discrimination of responsive penetration aids. Discrimination by perturbation or kill of penetration aids by directed energy weapons offers a confident backup to sensor-based discrimination. However, it requires a significant number of high-power directed energy weapons with very fast retarget times. Discrimination by neutral particle beams requires a large number of adjunct radiation detection sensors in space.

<u>Survivability</u>

There is strong motivation for the threat to suppress a U.S. strategic defense system and thereby restore the effectiveness of its strategic nuclear ballistic missile forces. The defense, in turn, must be designed to operate in any environment the offense may create. Achieving defense mission objectives in the face of all responsive threats must be achieved.

<u>Space Logistics</u>

Several strategies may be considered for optimizing the SDI system design and configuration with respect to logistics, producibility and cost. One major cost of the overall SDI system, when configured with a robust space-based capability, is the launch cost associated with the initial system deployment. Another is the cost associated with maintenance and replacement functions that are required to maintain continuous operation.

The development of very large, integrated launch vehicles capable of lifting 200 MT (Metric tons) into orbit appear to be unjustified unless large numbers of very large, integrated space assets are intended for launch. If on-orbit maintenance is considered, assembly in orbit from the payload of two 90 MT launch vehicles may be cheaper. The recovery and servicing options could make use of advanced technology in fully reusable launchers with a 70 MT capability for recovery operations and a 15 MT capability for performing on-orbit servicing.

Production and Cost

Reducing production costs for space platforms, weapons, and sensors and for the large number of midcourse interceptors offers the greatest potential for improving the affordability of multilayer defenses. The existing cost data base for military space systems is derived from experience with programs in which small numbers of satellites, often of new design and at the leading edge of technology, are produced and tested largely by hand. A new way of producing space components that takes advantage of new technologies, new designs for producibility, more automated manufacturing techniques, and economies of scale is needed to significantly reduce space system costs.

New cost models are needed to price the new designs and methodologies for high efficiency, high volume and low cost production of components for the defense systems. Current models are poor, because they are based on quite different ground rules, as noted above.

Battle Management/Command, Control, and Communications (BM/C^3)

The state-of-the-art in computer hardware is advancing very rapidly. It is expected that requirements for SDI processing can be met in the early 1990s with radiation hardened processors. Strategy to emphasize processor hardware solutions rather than software solutions appears to offer potentially high payoff, especially when designed into the system architecture.

Design simplicity and modularity result in simplified and more effective software development. Software modularity is the characteristic which allows use of the same or derivative software in multiple applications. Modularity and simplicity also aid development of reliable and fault-tolerant software.

The initial space-based architecture led to a highly proliferated, distributed BM/C^3 architecture containing no identifiable critical modes. This was to enhance survivability of the BM/C^3 function and to provide effective command and control of a globally distributed configuration of weapon and sensor platforms. Decentralizing BM/C^3 architecture and reducing interdependence has resulted in a more resilient system.

Timely weapon release of the SDI defense system is important, especially for boost phase defenses under ASAT attack. Therefore, special attention has to be paid to the interfaces between man and machine.

CHAPTER VII
THE TECHNICAL CHALLENGE

A. OVERVIEW

Three years have passed since President Reagan announced his defense initiative and called for an intensive and comprehensive effort to define a long term program. His confidence that it was time to pursue such a program was based on two major assumptions. First, technology had reached a point that showed great promise and secondly, the nation had the technological potential to bring the promise to reality.

Building upon the foundation spelled out in the Fletcher Report, a sound technical program was defined and put into action. Technical efforts have been structured into five program elements, each element examining equally crucial SDI technology. The material in this chapter is organized to describe each program element and the progress that has been made to date. A discussion of the major focus for FY 1987 and plans for the future including major milestones is also included. Detailed descriptions of these programs can be found in the FY 1987 Descriptive Summaries submitted to the Congress in February 1986.

Recognizing the importance of innovation, the SDIO has organized an activity, in addition to the five program elements, to promote inventive ideas. A fixed fraction of each program element is set aside to fund promising concepts. Work on promising concepts is characterized by high risk, high payoff, low cost research that can be performed anywhere (laboratories, small business, industry, universities) and by anyone. The work involves unclassified fundamental research, and its results, once evaluated, will help create new opportunitites for all the other program elements.

The technical program is organized to support future decisions on defensive options. To do this, diverse efforts producing essential answers to critical issues must converge. Among the important critical issues requiring resolution to be recently identified are:

- The need for "smart" high speed kinetic kill projectiles. That type of projectile will help assure the viability of a kinetic energy alternative for boost phase kill;
- Good "windows" in the high-endoatmospheric regime and good discrimination for exoatmospheric interceptors;
- Hypervelocity, repetitively-pulsed rail guns with "smart" bullets;
- Active discrimination using RADAR and/or LADAR and interactive discriminators using lasers and neutral beams;
- Hardening of passive sensors to hostile environments;
- Booster "hardbody" identification in the presence of the rocket's "plume";
- High brightness lasers, particle beams, and nuclear-driven technology for boost-phase intercept against "responsive" threats;
- Battle management/C^3 software and hardware including a simulation and testing ground facility;
- Survivability and countermeasures work by systems technologists;
- Lethality experiments carried out at levels characteristic of realistic weapons on realistic targets;
- Space-based power supplies and power conditioning equipment; and,

- Reduction in space transportation costs.

Due to the complexity of the SDI research program, a number of issues must be resolved before a decision can be made to proceed to the development phase. Discussion in this chapter on the various accomplishments of each facet of the program has made in the last several years points out that the answers to these issues are beginning to emerge.

Typically, as a given technology matures, new questions arise as old ones are answered. Sometimes the more mature technologies appear less promising than other less well researched technologies that have not, as yet, encountered the tougher questions. Care has to be taken to avoid being overly critical of concepts well along in research or to expect too much from concepts not yet put to the test. The SDI program described in the following sections is designed to bring along the emerging technologies in a logical, timely way--that is the technical challenge.

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B. SURVEILLANCE, ACQUISITION, TRACKING AND KILL ASSESSMENT (SATKA) PROGRAM

Technical Objectives - The Role of SATKA in the SDI

The SATKA Program provides research efforts necessary to identify and validate various sensor concepts for performing surveillance, acquisition, tracking, discrimination and kill assessment of enemy ballistic missiles from their launch to warhead reentry and detonation (birth-to-death). There are three basic sensor suites to accomplish these functions:

- Rocket launch detection sensors that sense the initiation of the attack and provide initial tracking data to assess the attack, bring boost phase interceptors to bear, and provide data to assist in kill assessment.
- Midcourse surveillance and discrimination sensors that track reentry vehicles, decoys, chaff and other debris that constitute the threat cloud released at the end of the boost phase. Sensors that provide data that can help discriminate decoys, chaff, and debris from the reentry vehicles carrying the warheads, provide the predicted positions of targets to bring the midcourse intercept weapons to bear, and assist in kill assessment.
- Terminal phase surveillance that can--in the few tens of seconds it takes for the attacking warhead to enter the atmosphere and detonate--acquire, track, and collect data on the behavior of reentering objects in the atmosphere to support discrimination, predict intercept points and assess kills.

In the boost phase, sensors must provide rapid and reliable warning of attack as soon after launch as possible. One such concept is the Boost Surveillance and Tracking System (BSTS) shown in Figure VII.B.1. The BSTS must be highly survivable to direct attack during the battle. It must also endure after the

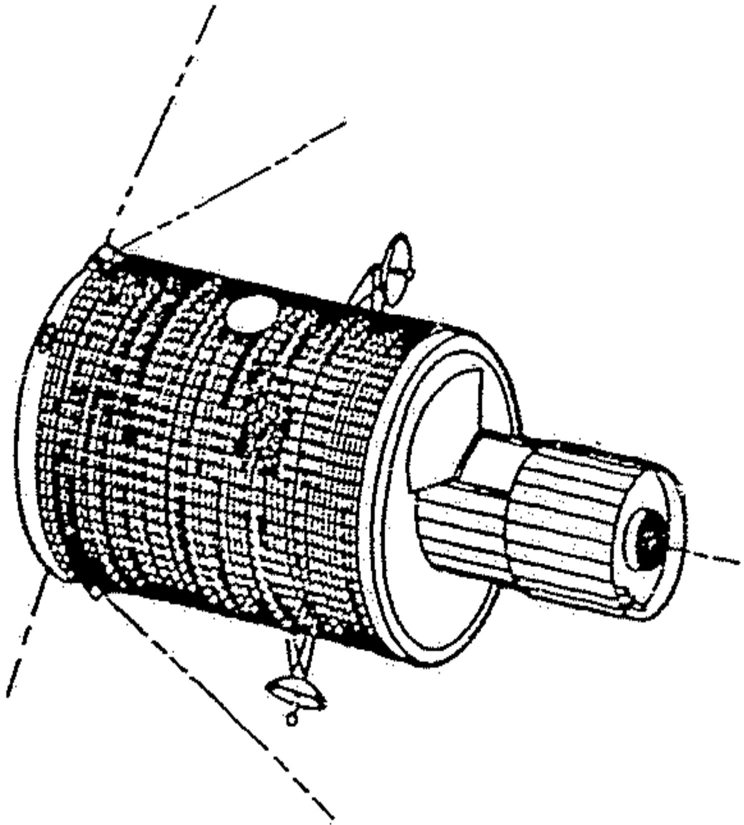

Figure VII.B.1. Boost Surveillance and Tracking System (BSTS)

boost phase battle is finished, as this function is essential for warning, assessment, and handover to other defense elements.

In the post-boost and midcourse phases, sensors must provide accurate and efficient tracking and discrimination between reentry vehicles, lightweight penetration aids and other debris. Midcourse surveillance systems must be capable of accepting track files from boost phase surveillance. These systems must also provide track data for hand-off to post-boost and midcourse interceptors, as well as terminal phase tracking systems. One such concept is the Space Surveillance and Tracking System (SSTS) shown in Figure VII.B.2.

The SSTS would provide a near real-time, fully responsive space-based system for midcourse ballistic missile surveillance and tracking, and timely satellite attack warning and verification.

In the terminal phase, sensors must provide efficient tracking and discrimination of RVs from penetration aids and other debris based on radiometric and ballistic information. Systems must be capable of receiving track information from midcourse sensors, tracking the target, processing the data, and passing commands to intercept vehicles.

The Airborne Optical Surveillance (AOS) concept is an aircraft-based, late midcourse and terminal phase acquisition, tracking and discrimination system capable of hand-off to a ground-based surveillance system for terminal intercept.

The Terminal Imaging Radar (TIR) concept shown in Figure VII.B.3 could receive the handover from an Airborne Optical Surveillance system. The TIR could then provide precision track information for high endoatmospheric terminal phase engagements of the most threatening objects.

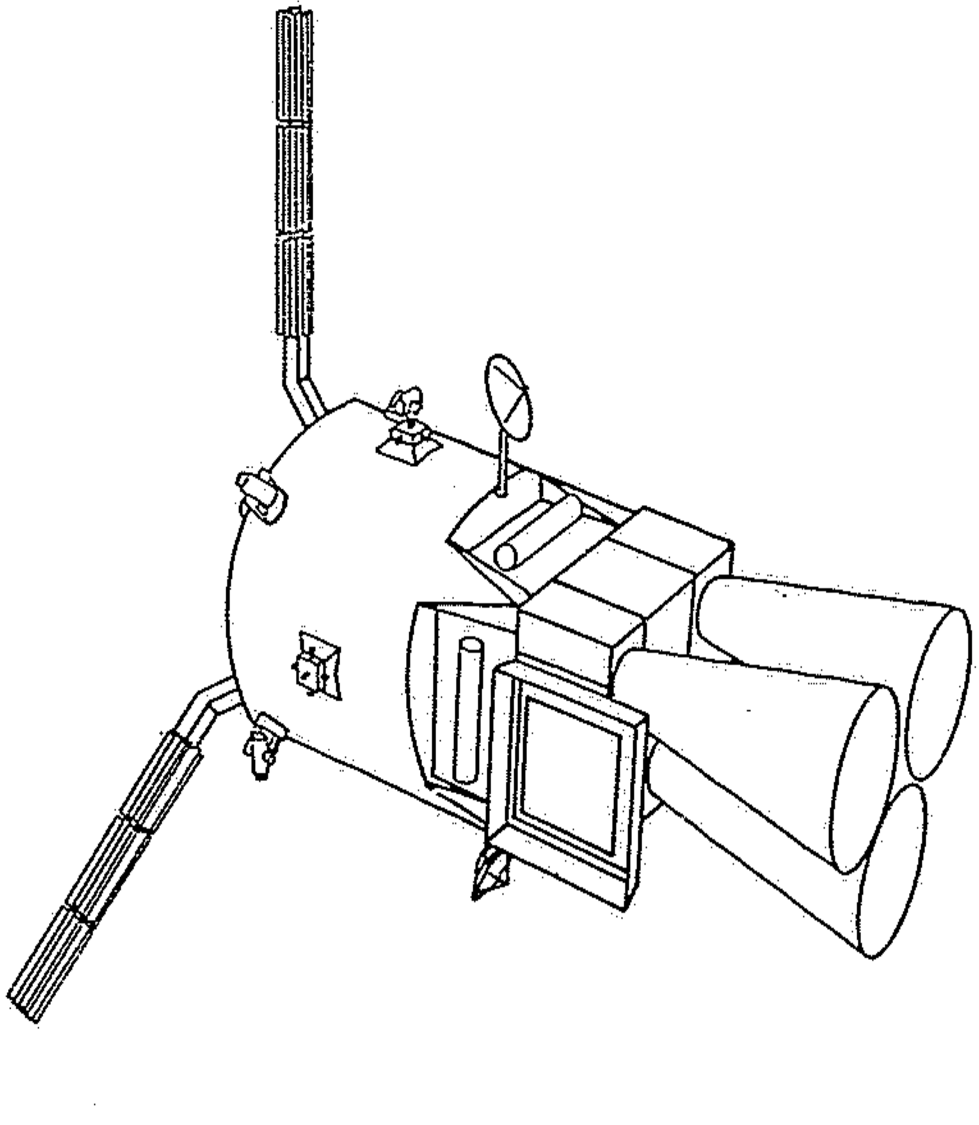

Figure VII.B.2. Space Surveillance and Tracking System (SSTS)

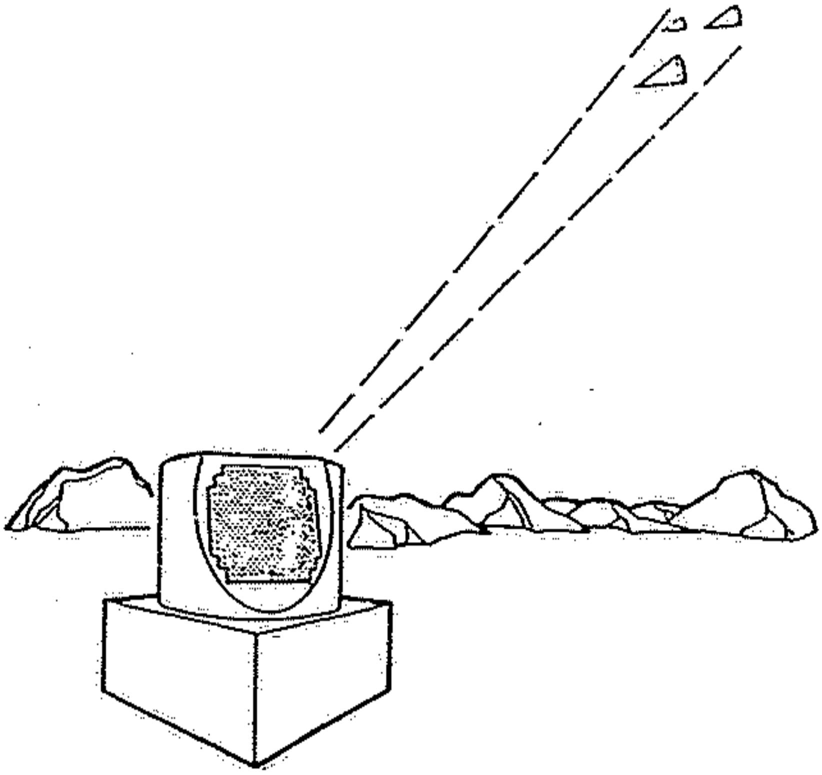

Figure VII.B.3. Terminal Imaging Radar (TIR)

Significant SATKA Accomplishments (FY 1984-1985)

Technologies

- In the area of infrared (IR) sensors, cryocoolers have been developed that are undergoing life testing that should increase sensor performance.
- The SDI Radar Discrimination Study has been completed.
- In the area of signal processing, Gallium Arsenide (GaAs) pilot production lines are now operational. A five node prototype Advanced Distributed Onboard Processor (ADOP) was delivered and installed at the Advanced Research Institute, Huntsville, AL.

Experiments

- Requirements definition for BSTS and SSTS have been completed.
- Fabrication of Airborne Optical Adjunct (AOA) experimental hardware has been initiated.
- Concept definition for the AOS experiment and the Laser Ranger have been initiated.
- Preliminary design contracts for TIR have been initiated.

Measurements

- A rocketborne earthlimb viewing auroral experiment called SPIRIT I was completed and sent to Alaska.

Overview of the SATKA Program

To accomplish the stated technical objectives and to provide confidence necessary for an early 1990s decision, the SATKA Program has three basic components: technology development, experiments, and data collection.

- Technology Development. The SATKA Program performs research in those areas of the technology base

which support the very high capability sensors required by SDI. These efforts are concentrated in five areas: Radar Technology (Project 3); Laser Radar Technology (Project 4); IR Sensor Technology (Project 5); Interactive Discrimination (Project 10); and Signal Processing Technologies (Project 11).

Experiments. The SATKA Program contains a number of experiments designed to validate the various concepts which have been proposed. Advanced sensor technology efforts determine the capabilities of such sensors and provide data necessary for future decisions. These include Boost Surveillance and Tracking Experiment (Project 6), Space Surveillance and Tracking Experiment (Project 7), Optical Airborne Surveillance Experiment (Project 8), and Terminal Imaging Radar Experiment (Project 9).

Data Collection. This project provides both radar and optical discrimination technology and data base for the collection and eventual interpretation of data on ballistic missile elements. Principle tasks include Cobra Judy, post-boost vehicle (PBV) data collection, infrared (IR) exoatmospheric and high endoatmospheric signature data, and IR background.

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C. DIRECTED ENERGY WEAPONS (DEW) TECHNOLOGY PROGRAM

Technical Objectives - The Role of Directed Energy in the SDI

The Directed Energy Program identifies and validates the technology for directed energy systems that can:

- Destroy large numbers of enemy boosters and post-boost vehicles in the tens to a few hundreds of seconds that the missiles are in their boost phase; and
- Discriminate decoys from warheads by probing them with a directed energy beam that interacts with the target and scatters radiation from the nuclear warhead or creates other identifying signatures.

These two missions, boost-phase intercept and midcourse discrimination, are the keys to achieving high levels of ballistic missile defense effectiveness against the most capable threats. Thus, technological advances supported by this program element are critical in providing a wide selection of defense options for the President's SDI.

In the earliest potential defense deployments, directed energy concepts could provide the primary candidates for interactive discrimination in the midcourse phase. In addition, they could provide alternatives to kinetic energy weapons for boost-phase intercept. Over the long term, directed energy weapons appear to hold the key to defeating some of the more stressing threats that might be deployed in response to U.S. defense deployments (such as the fast burn booster which could severely shorten the exposure time of enemy missiles in their vulnerable boost phase).

Efforts in this program pursue directed energy weapon concepts that include not only those that have emerged since the start of the Initiative but also those that predate the Initiative by several years and are more technically mature.

The program also emphasizes innovative technology. New forms of directed energy weapons concepts are continually emerging and creating options that may offer significant system performance improvement and/or cost reduction. Four basic concepts are addressed with several potential variations identified within each concept. These concepts are: space-based lasers (SBL), ground-based lasers (GBL), space-based particle beams (SBPB), and nuclear directed energy weapons (NDEW).

The space-based laser (SBL) concept (depicted in Figure VII.C.1) envisions self-contained laser battle stations. These battle stations are seen as modular assemblies of laser devices and optical phased arrays that grow in performance as the threat grows by adding additional modules. These stations are deployed in orbits that ensure the required number of weapons can be available to engage ballistic missile launches wherever they occur. Once deployed, SBL stations can engage ballistic missiles launched from anywhere on the earth including the broad ocean area for sea-launched ballistic missiles and Western Europe for intermediate range ballistic missiles. The same constellation of SBL battle stations could play other very significant roles. They can engage threat objects and destroy post-boost vehicles before all reentry vehicles are deployed; destroy decoys or penetration aids in the midcourse phase; and defend U.S. satellites. Furthermore, since the beam of some lasers could penetrate into the atmosphere down to the cloud tops, SBL weapons may be able to provide some capability against aircraft, cruise missiles, and possibly tactical ballistic missiles.

The primary approach to the space-based laser concept uses hydrogen-flouride fueled chemical lasers of 2.7 micrometer wavelength. This concept has been in research since the late 1970s. As the first of the DEW concepts identified for application

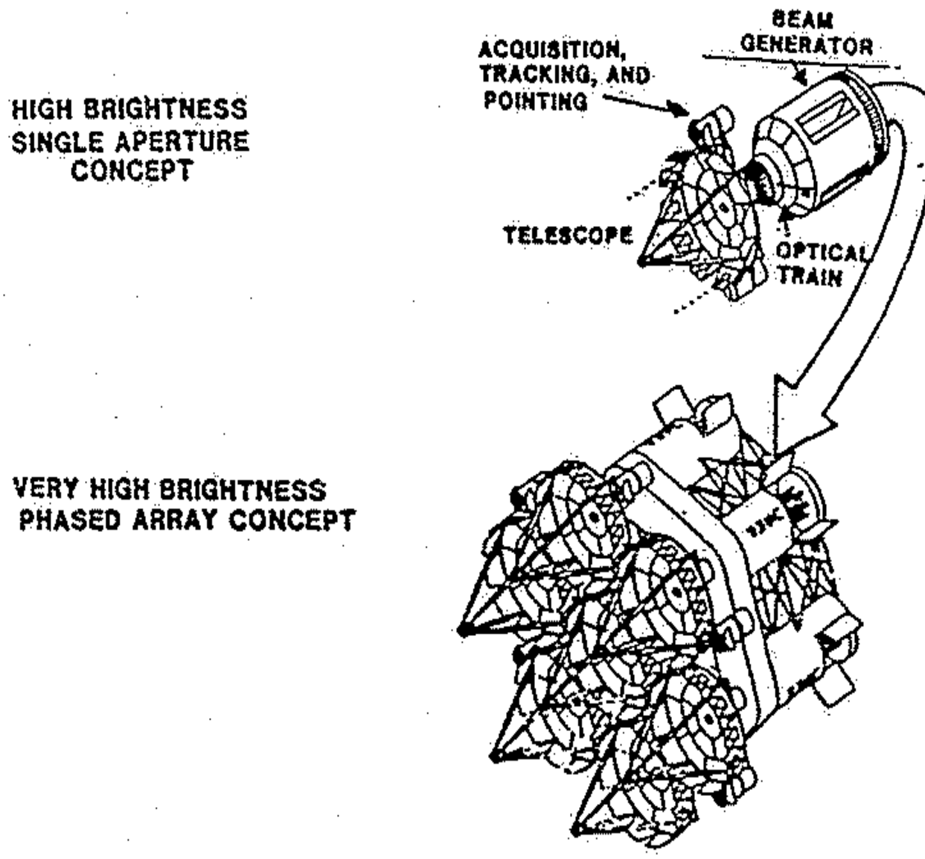

Figure VII.C.1. The Space-Based Laser Concept

against ballistic missiles, it has the most mature technology base. Efforts are well into the hardware fabrication phase for engineering proof-of-principle through ground-based tests.

Other candidates for space-based lasers are based on devices that generate beams at short (one micrometer or less) wavelengths. Substantial increases in brightness (a primary measure of performance) can be realized if the quality of the optics and accuracy in pointing can be increased. The radio-frequency linac (RFL) free electron laser (FEL), for which high electrical efficiencies are projected, is one of the most promising alternatives. Another potential alternative is the short wavelength chemical laser although to date, no concept appears to be viable. Another approach is the use of nuclear reactors to pump the laser.

Ground-Based Lasers

The ground-based laser (GBL) concept depicted in Figure VII.C.2 uses several ground sites equipped with laser beam generators, target acquisition, tracking, pointing, and advanced beam control. Each station generates a beam transmitted through the atmosphere to space. There the beam is projected onto space relay mirrors. These relays collect the beams from the ground and redirect them to mission mirrors. The mission mirrors collect the beam from the relay, acquire and track the target, point the beam at the target, and focus the beam on the target.

Space-Based Particle Beams

The space-based neutral particle beam (SBNPB) concept is depicted in Figure VII.C.3. In this concept, negative ions are accelerated by electro-magnetic fields in much the same way as conventional accelerators when used by particle physicists to explore the atom. Large numbers of these particles are accelerated to velocities near the speed of light, creating a high energy beam which is steered toward the target by magnets at

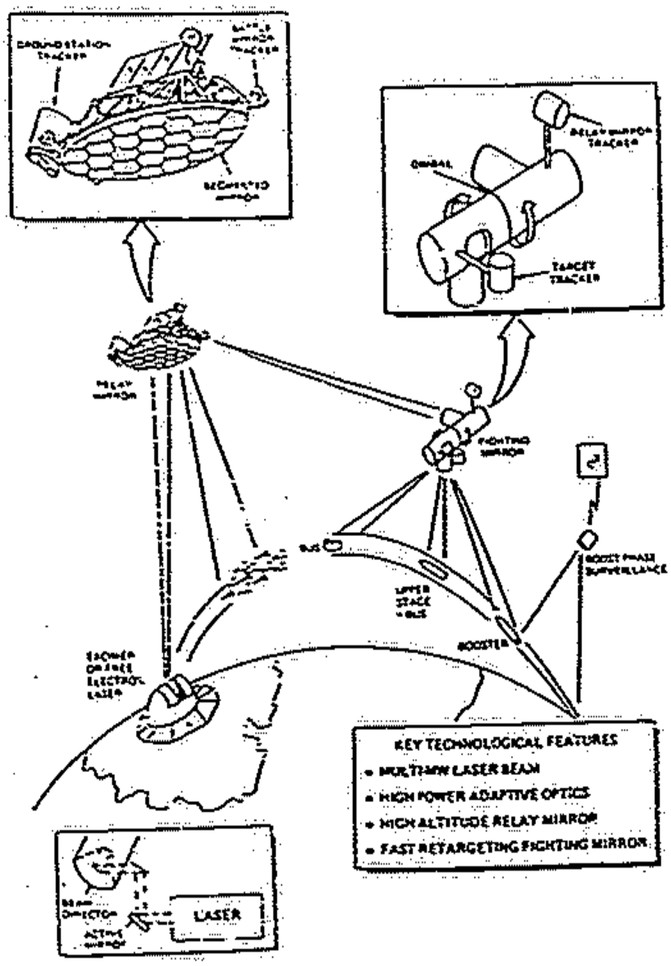

Figure VII.C.2. The Ground-Based Laser Concept

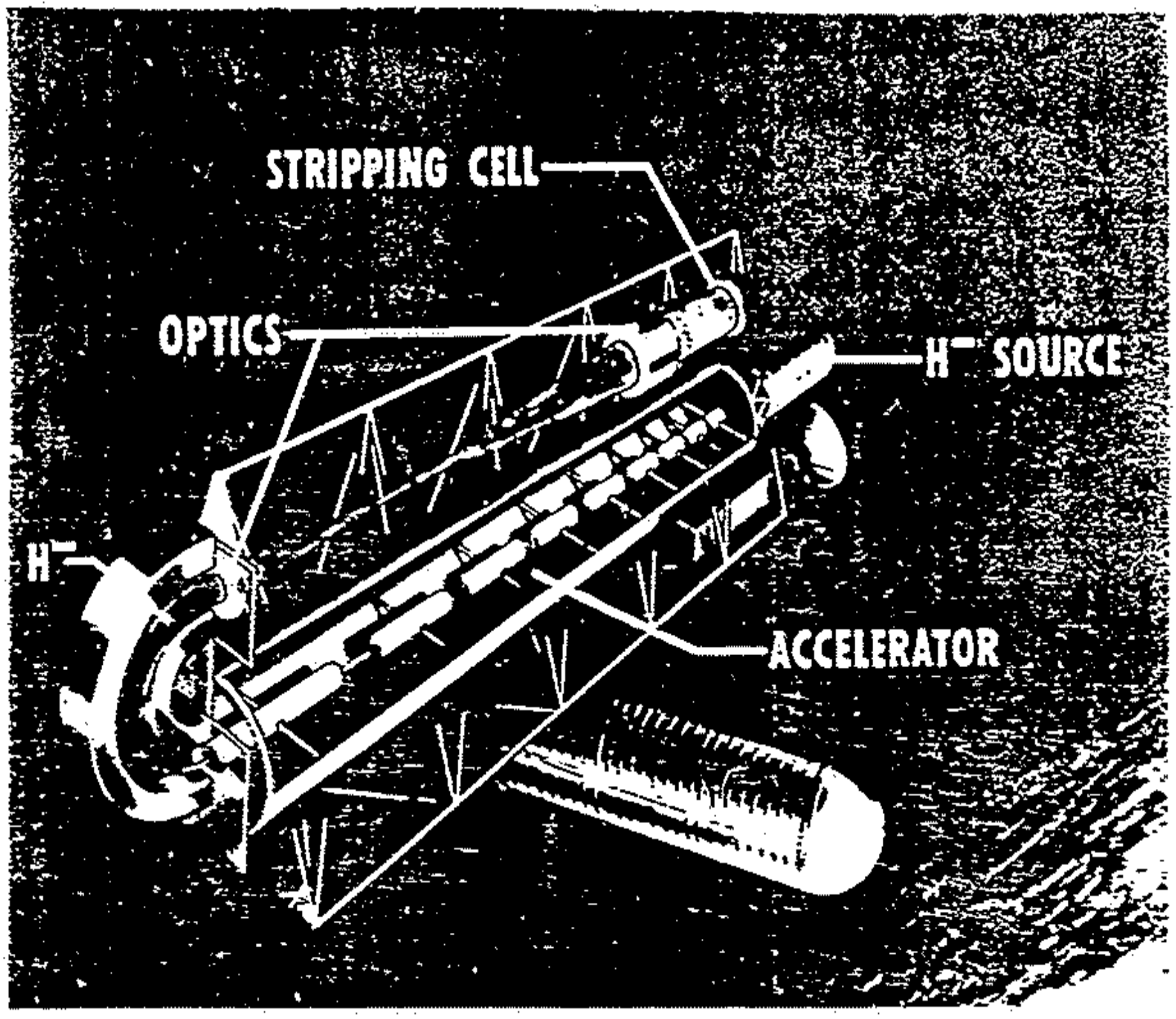

Figure VII.C.3. The Neutral Particle Beam Concept

the front of the weapon. In the neutral particle beam concept, the particles are stripped of their negative charge as they leave the weapon. This neutral beam then will stay together as it leaves the accelerator. (If the beam were not neutralized in the vacuum in space, the like charges of the individual particles would repel each other and break up the beam. In addition, the particles would be unacceptably deflected by the earth's magnetic field.) A second approach for targets at lower altitudes uses charged particle beams which follow an ionized channel. This channel is created by a laser beam in the thin upper atmosphere and forms a conducting path to the target.

The neutral particle beam weapon concept, like space-based lasers, visualizes a configuration of battle stations in space that provides worldwide coverage. These stations could be capable of engaging ballistic missile boosters and post-boost vehicles as their trajectories bring them above the earth's atmosphere. Unlike lasers, the energetic particles or ions penetrate deep into the target. Thus a high brightness particle beam can penetrate the thermal protection of a missile provided to survive reentry, and engage reentry vehicles in the midcourse trajectory.

Such a weapon has two potential kill mechanisms. First, electronics kill might be possible at relatively low beam fluence levels. However, it may not be possible to tell that the target has been killed. Hard or structural (readily observable) kill requires fluence several orders of magnitude greater than electronics kill. Efforts in this concept and its associated technology were proceeding at a fiscally-limited pace prior to the Initiative and were accelerated as a result of the SDI.

The newest, and potentially the earliest, application of space-based particle beam battle stations could be the discrimination function during post-boost and midcourse phases.

Primary targets would be decoys that are difficult to detect using passive means. Gamma-rays and neutrons emitted by an object when irradiated by an energetic particle beam increase in proportion to the size of the object irradiated. Thus, these emissions can serve as a discriminant between heavy re-entry vehicles and the light decoys and/or penetration aids that may be encountered during an attack. Effective discrimination would decrease substantially the false targeting rate, thus conserving midcourse and terminal interceptor resources.

Significant DEW Accomplishments

Some specific examples of recent technical accomplishments in the field of directed energy are:

- Completion of the fabrication phase of the optical resonator and demonstration that a high quality beam can be extracted from a cylindrical chemical laser. These experiments substantially increase confidence in the success of the ALPHA project--the basic beam generator for space chemical laser concepts.

- Ability to couple multiple lasers into one coherent output. These experiments under the advanced chemical lasers task are critical accomplishments in our efforts to show that small modular devices can be coupled together to yield very high power/high brightness chemical lasers.

- Initial experiments on hierarchical beam control using the laboratory brassboard of the Large Optics Demonstration Experiment (LODE). The results have markedly increased our confidence that baseline beam control architectures for space-based lasers are viable.

- Validation of the fabrication process for the Large Advanced Mirror Program (LAMP). Validated at half scale, LAMP results give high confidence that the

program will achieve a near order-of-magnitude reduction in areal density (kg/m^2) over that of the NASA Space Telescope, with segmented elements scalable to sizes that far exceed the diameter of the primary mirror in that NASA spacecraft.

Completion of a Large Optics Diamond Turning Machine (LODTM) facility that will permit precision fabrication of the complex mirror elements. Built to fabricate the cylindrical shapes for the ALPHA laser, this facility represents a major breakthrough in near IR optical fabrication technology and a major step toward realizing space-based lasers.

An order of magnitude improvement in beam emittance, new "magnetic modulator" power switches, and confirmation of the basic electromagnetic theory of the induction linac FEL amplifier concept. Recent experiments have demonstrated laser gain and energy extraction efficiency at power levels that helped confirm the fundamental validity of this approach.

Experimental evidence of major advances in efficiency, beam quality, peak power and wavelength scalability of the radio frequency linac, free electron laser. Major achievements also include demonstration of diffraction limited beam generation with wavelength tuneability over a broad band. As in the case of the induction linac FEL, new insights in FEL theory and the resulting improved performance prediction have resulted.

Generation of a near diffraction limited beam in the excimer laser technology efforts on a single pulse basis. This excellent beam quality reduces the power required from the device for the GBL mission. In addition, advances in high power electrical pulse conditioning, high efficiency, large

area electron guns, and acoustic damping also give increasing confidence in the excimer technology.

Proof-of-principle of the Raman conversion process on a laboratory scale. This process offers potential for major reductions in the complexity (and cost) required to achieve high beam quality output from excimer lasers. This process also offers a practical approach for achieving the single aperture high power levels and beam quality required for excimer laser weapon applications.

Demonstration of atmospheric compensation in an extensive series of experiments involving propagation of a low power laser beam from a fixed ground site to an instrumented aircraft and sounding rockets that dramatically demonstrated our ability to reduce the deleterious effects of atmospheric turbulence on laser beam propagation.

Fabrication and testing of the radio-frequency quadrupole pre-accelerator section on the Neutral Particle Beam Accelerator Test Stand. This device, which both accelerates and bunches a charged ion beam, is considered a major step forward in ion beam accelerator technology. In addition, a pulsed negative ion source has produced a better ion beam quality than its design goal.

Demonstration of a technique suitable for precision boresighting of the neutral beam with respect to an optical tracker line-of-sight. These significant results and accelerator advances cited above provide significant new evidence that neutral particle beams have practical applications in near-earth space for both interactive discrimination and weapons missions.

Overview of the DEW Program

DEW research efforts are consolidated into four principal projects under the program managed by the Directed Energy Office. These projects are Technology Base Development, Technology Integration Experiments, Concept Formulation and Technical Development Planning, and Support Programs.

The Technology Base Development Project maintains an aggressive effort to expand the technological basis for directed energy systems. The project makes available alternative paths for achieving the critical functions of boost-phase intercept and discrimination in addition to those pursued in the technology integration experiments. To achieve this goal, the technology base must advance DEW technologies that perform the functions of (1) generating the beam; (2) conditioning the beam and delivering it for propagation toward the target; (3) focusing and propagating the beam at the target along a prescribed path; and (4) acquiring the target for the beam, establishing the line-of-sight to hit the target, holding the beam on the target, assessing the resulting damage, and then reinitiating the sequence to engage rapidly a new target.

Thus, this project includes work on laser devices at various wavelengths; laser beam control and associated optics; particle beam technology, acquisition, tracking, pointing and fire control (ATP-FC); and nuclear directed energy weapon technology.

Technology Integration Experiments are proof-of-feasibility efforts which integrate and validate technology for selected concepts. These projects include (1) Ground-Based, Induction Linac, Free Electron Laser; (2) Neutral Particle Beam (NPB) Interactive Discrimination; and (3) Space Pointing and Tracking Experiments. These major experiments provide leverage for opportunities in realizing significant experimental gains for specific promising concepts for boost-phase intercept and midcourse discrimination. Their selection

to receive emphasis, as a major project receiving major resources, places them on the leading edge of the SDI Directed Energy Program. In space experiments in tracking and pointing, they are designed to have broad applicability across a range of SDI concepts, including non-DEW concepts.

The other two projects under the Directed Energy Program are Concept Formulation and Technical Development Planning, and Innovative Science and Technology and Support Programs. Concept Formulation and Technical Development Planning funds activities that guide Directed Energy Weapons technology development efforts by reviewing and evaluating technical requirements. The project also provides conceptual designs of operational systems related to architectural structures which emerge from efforts within the Systems Development Program Element. These planning activities help identify and resolve critical DEW issues on a scale that establishes the technical feasibility of achieving weapon-level performance.

Support Programs partially fund activities at the DoD High Energy Laser Systems Test Facility (HELSTF) at White Sands Missile Range. This facility provides equipment and facilities for integrated high energy laser experiments as well as lethality and vulnerability testing of potential targets using a high power deuterium fluoride (DF) laser. A second effort funded under this project, Targets, supports planning, procurement, operations, and maintenance activities for the targets of DEW Major Experiments. This project also funds the DEW portion of the Innovative Science and Technology Program, described in Section VII-G.

D. KINETIC ENERGY WEAPONS (KEW) PROGRAM

Technical Objectives - The Role of KEW in the SDI

Activities in this program support weapons options for all phases of a multitiered defense. As a relatively mature set of technologies, these efforts are not only a major candidate for providing the intercept and kill functions of any initial ballistic missile defense deployment but provide the major contribution to a hedge against a Soviet breakout of the ABM Treaty.

Kinetic energy guided projectiles can be accelerated by chemically propelled boosters or, in the longer term, by hypervelocity electromagnetic means. In either case, projectiles rely on nonnuclear kill mechanisms. The kinetic energy program is developing technology for: (1) space-based, rocket-accelerated kinetic kill vehicles (KKVs) for ICBM intercept and satellite defense; (2) ground-launched, high-velocity, high endoatmospheric interceptors; (3) ground-launched, exoatmospheric interceptors; (4) advanced hypervelocity rail guns; and (5) support items, such as fire control components that cover all aspects of kinetic energy weapons.

Key technology developments needed are seekers, divert (maneuver) propulsion, axial (booster) propulsion, fire control, guidance and control, warheads and fusing. Proof-of-principle experiments are being designed to support a system level decision in the early 1990s time frame.

Chemical rockets are in a more advanced technologically status than are hypervelocity, electromagnetic guns. The latter become favored over rockets for applications in which very large numbers of engagements must be accommodated. Hypervelocity guns are also attractive because of their ability to achieve shorter flyout times with minimal system weight impact. These advantages accrue since only the kill vehicle leaves the rail gun, as opposed to the kill vehicle plus propellant in the

case of a rocket. On the other hand, the electromagnetically-accelerated projectile experiences much higher g-forces than the rocket-accelerated projectile.

It should also be noted that kinetic weapons are very useful in the defense of space platforms. Performance objectives are a function of the altitude and hardness of the space-platform orbit, threat yields and arrival rates, and threat numbers per platform.

Significant KEW Accomplishments (FY 1984-1985)

Over the last 2 years the kinetic energy weapon program has produced several accomplishments. The most significant of these is the demonstration of an actual reentry vehicle mid-course intercept in the Homing Overlay Experiment (HOE) conducted by the Army. This experiment was conducted with an interceptor which was initially given intercept point information and then switched to autonomous terminal homing, the same crucial functions most probably necessary for eventual weapons systems. Other major kinetic energy technology accomplishments include testing of elements such as divert propulsion thrusters and propellants necessary for light-weight interceptor fabrication. In addition, detailed analysis has been completed to define the performance requirements (for example, axial and lateral velocities) necessary for various interception scenarios. In the hypervelocity launcher area, a number of laboratory devices have been utilized to test the feasibility of multiple shots with a single gun barrel and the feasibility of high-g survivable projectile components.

An Overview of the KEW Program

In order to accomplish stated technical objectives and to provide the confidence necessary for an early 1990s decision, the KEW program has six major components--(1) space systems for boost phase intercept; (2) exoatmospheric nonnuclear kill interceptors; (3) endoatmospheric nonnuclear kill interceptors;

(4) capabilities against shorter range threats; (5) electromagnetic accelerators; and (6) testing and facilities support. The first five components have an associated technology base activity and major experiments.

In technology base activities, technologies relating to precision KKV projectiles accelerated by rockets or hypervelocity guns will be explored to provide potential nonnuclear kill of ballistic missiles in all phases of flight--boost, midcourse, and terminal. Technology base efforts include:

- Smart seekers to acquire targets rapidly and provide highly accurate terminal homing;
- Advanced guidance and control techniques to control KKV maneuvers for direct impact with targets;
- Miniature rocket vehicles for boost and midcourse ballistic missile intercept, as well as for satellite defense; and
- Electromagnetic accelerators and smart hypervelocity gun projectiles.

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E. SYSTEMS ANALYSIS AND BATTLE MANAGEMENT (SA/BM) PROGRAM

Technical Objectives - The Role of SA/BM in the SDI

Diverse but related activities included in the Systems Analysis and Battle Management Program of the SDIO provide two key criteria that drive the other SDIO Programs. The systems analysis efforts define the performance regimes of the individual systems that will make up the defense architecture that must be met if cost-effective defenses against responsive threats are to be realized. Battle management efforts define the operational environment of decisions, rules, constraints and directions in which individual systems must perform.

Systems analysis provides an approach that assists the managers of the SDI in choosing courses of action to conduct their research projects. Through a series of studies, analyses and evaluations, the Director, SDIO and his subordinates are provided with investigations of the full range of technical issues and problems, the identification of relevant objectives and alternatives, and analytical comparisons of those objectives and alternatives in light of their consequences. In the process an appropriate framework is created to bring expert judgment and intuition to bear on the choice among the promising approaches to achieving effective defenses and the design and development of the weapon systems that constitute those defenses.

The four main thrusts of this Program are described in the following paragraphs.

Systems Analysis

Systems Analysis Technical Objectives

The Systems Analysis project is comprised of several tasks which seek to establish system architectural alternatives based on defense missions and objectives, threat assessments and weapon/sensor technology integration. These candidate

architectures will be used to define system component performance requirements. Results of this project will provide for technical program integration.

Significant Accomplishments (FY 1984-1985)

Emphasis in FY 1984-1985 was on defining the baseline threat and generating baseline SDI system requirements.

In coordination with the intelligence community and other SDI programs, a time-phased expected strategic threat and attack scenario was defined. Strategy and policy issues and constraints were regarded as inputs and outputs. Architecture methodology and selection criteria were developed. There was a continuation of analyses and evaluation of boost, post-boost, midcourse, and terminal phase SDI concepts initiated in the previous year. Strawman system conceptual designs and iterated allocation of resources and constraints among defense phases were developed in sufficient detail to document initially perceived SDI system requirements. Architectural systems and cost models with interactive application and refinement to the architectures were chosen on a more generic level. Examination of the impact of future technologies and national resources on strategic defenses, strategy and policy was begun.

Systems Analysis Project Description

The specific tasks with the Systems Analysis project include the Architecture task, the Threat Analysis task, the Technology Integration task and the Architecture Analysis Support task.

The Architecture task is structured to define and evaluate candidate system architectures, system concepts and parametric trade-offs leading to the evaluation of preferred architectures and allowing assessment of key technologies and system functions. Initially there were two basic efforts to define defense architectures. One was developed by a team from

Federal Contract Research Centers (FCRCs) and National Laboratories. This Pilot Architecture provided an early formulation of these system architectures and trade-offs. In a separate effort, industry contractors participated in the two phase SDI System Architecture and Key Trade-off Study. Ten participated in the first phase and provided an initial look at potential architectures while competing for the more detailed phase two efforts. Five contractors were selected and are currently providing conceptual architectures. Phase two will be complete by the end of FY 1986.

The Threat Analysis effort will provide projections of possible threat structures usable against the U.S. and its Allies. Analysis will also be performed to define responses which might be invoked to counter defense concepts.

There are three broad categories under technology integration: affordability, logistics integration, and technical integration. Within these categories, there are several tasks for accomplishment by the SDIO and the Services.

Studies and analyses related to the affordability of the SDI program will be performed under the affordability task. In particular this task provides the affordability analyses, innovative cost analysis and research, and industrial base considerations, to include production base analyses and manufacturing technology and producibility studies.

The logistics integration task addresses logistics and supportability elements will be addressed across the entire SDI program. Research and analyses to identify and quantify essential elements of an SDI logistics support system; the basic supportability costs, schedules, and performance drivers in each project; and related supportability technology requirements will be performed. It is through early emphasis on supportability that desirable support characteristics are

determined and considered in SDI research. Examples include appropriate levels of standardization and commonality, as well as reliability, maintainability, and system availability. This task is managed by the SLKT Directorate, previously entitled Space Logistics, which addresses space transportation and support.

Achieving a systematic and coordinated relationship among the diverse technical elements of the SDI will be analyzed by the technical integration task. This task includes the development and implementation of an overall technical integration program plan, a work package directive data base for risk analysis, and a technical facilities assessment. These functions will be accomplished through a topdown analysis of technical requirements within system architectures, and a bottom-up analysis of actual technical capabilities existing or projected.

The Architecture Analysis Support is structured to support the definition of boost, post-boost, midcourse and terminal system performance requirements. Detailed trade studies will be used to determine lower level system performance requirements and support cost-effective systems context to ensure that risk is properly assessed. This task will also analyze cross-cutting system functions such as discrimination, track data base and weapons assignment. These functions are pervasive throughout a multitiered defensive concept and must be planned in an integrated manner. These functional requirements include the battle management subsystem requirements, to which the BM/C^3 Technology and Experimental Systems projects must respond.

Battle Management/Command, Control and Communications (BM/C^3)

Battle Management/C^3 Technical Objectives

The primary objective of this project is to specify, design, develop, and verify the technologies required for battle management capabilities; command, control and communications

networks; and their interfaces. The goal is to provide effective capabilities to examine command control over a multitiered defense. Specific emphasis is on achieving the required battle management algorithms; reliable, fault-tolerant, high performance processing; communications and software.

Battle management for a multitiered defensive system employs a wide variety of algorithms performing such functions as situation assessment, damage assessment, defensive firing strategies, network management and many others. The algorithms must deal with complex engagement rules, multiple kinds of weapons, rapidly changing environmental conditions, and a large degree of uncertainty in the input data. While source specific algorithms must wait on a well defined system, the system constructs under consideration are comprised of many components (space, air and ground) which are widely distributed geographically. These individual components may have only limited data regarding the overall battle situation. A system such as this requires a class of algorithms which may be partitioned geographically, have distributed data bases and be required to operate effectively with partial loss of communication. The need for highly efficient computing algorithms in this environment presents a new and very strenuous challenge to the field of distributed computing.

One objective is to synthesize algorithms applicable to specific SDI architectures. A further objective is to develop the algorithm data base necessary to produce a coherent, integrated, survivable, secure and interoperable distributed system to support ballistic missile defense command and control applications.

Reliable fault-tolerant, high performance processing is essential for battle management of a future system based on SDI technologies. Much of this processing will be done onboard space vehicles where normal maintenance access is not available.

The processing power required will greatly exceed what can be expected from even the highest performance single computing machine. Thus, a distributed processor will be required. In addition, multiple processor architectures, because of their built-in redundancy, provide a compelling approach to fault-tolerance. However, in order to achieve the required high performance and fault-tolerance, extensive work is required not only on hardware elements but also on algorithms and software to effectively manage computing resources while providing reliable computing. For example, extreme care must be taken to ensure that the operating system does not become a computation limiting overhead in multiple processor configurations.

Communication networks are integral to the Strategic Defense Initiative and are embedded in virtually every aspect of ballistic missile defense capability. Communications network planning and design for SDI will be heavily influenced by the requirement for the most stringent survivability measures. Objectives of the communications research tasks are to define communications network and technology requirements, to develop candidate network architectures to satisfy perceived system requirements, and to test network robustness and technology solutions in simulated threat environments. This research is aimed at providing high confidence for making programmatic decisions necessary to realize future communications networks for ballistic missile defense.

The battle management software to be developed for the SDI may be the most complex ever attempted. To be reasonably certain it will be developed on time, within schedule, and will correctly and safely implement the functionality of the system the labor intensive aspects of the software development, test, and maintenance processes must be made efficient and trusted. By automating significant parts of these processes, consistency, completeness and correctness can be better assured, and dependency on specific individuals lessened.

Software for a multilayered ballistic missile defense will be very complex, not only due to the amount of software required, but also due to the functions to be carried out by software. The complexity will directly relate to requirements for large software systems that can be explicitly trusted to carry out mission requirements. The software will need to be reliably modified and adapted to changing defense needs, and which can be guaranteed to have desirable behavior under all conceivable stressing conditions.

The basic objective of software research is to provide techniques, tools, facilities and methodology required to support battle management software development. A major milestone of this program will be a software engineering system encompassing all high-payoff tools and methods in FY 1989.

Significant Accomplishments (FY 1984-1985)

Requirements for a set of benchmark algorithms were developed for use in evaluating processor performance. A consortium of universities has been established to evaluate the role of knowledge-based and artificial intelligence for BM/C^3. A distributed algorithm test bed has been established for BM/C^3 algorithms testing and evaluation. Network protocol requirements have been defined and techniques for network control are being assessed for BM/C^3 architecture alternatives. Alternatives for establishing network synchrony have been developed and tested. Initial architecture requirements have been specified for fault-tolerant, distributed processors and developed specifications for space-qualified, radiation-hardened components. Specifications have been developed for millimeter-wave elements for space-to-ground C^2 links. Communication link requirements for characterization and definition have been produced. An initial set of automated software development tools that are being assessed for their efficacy in an integrated, automated software development environment also were developed.

Battle Management/C^3 Technology Project Description

Five tasks are pursued in the Battle Management/C^3 technology project: battle management algorithms, network concepts, processors, communications and software engineering.

The battle management algorithms task undertakes research of underlying technology, and, in parallel, of a candidate set of algorithms which will be required. The work will rely heavily upon previous and ongoing algorithm work in distributed systems, decentralized control and resource management (such as, Navy battle group defense). These technologies and algorithm studies will be integrated and the appropriate data base will be generated through experimentation in a BM/C^3 test bed. Specific attention will be given to system level algorithms which are peculiar to SDI layered defense concepts and are not being addressed in other program elements or in other SA/BM tasks. These algorithms are: (1) discrimination decision making, based on data collected by the system of sensors, available intelligence data base and system resource constraints; (2) boost phase and midcourse weapon assignment algorithms accounting for multiple types of weapons in each phase, the presence of succeeding phases, and the existence of constraints such as illuminator availability for midcourse intercepts; (3) discrimination sensor allocation during the midcourse, and particularly the deployment phase to maximize overall system effectiveness; (4) kill assessment in all phases; (5) reconfiguration of the system when weapon, surveillance, and/or BM/C^3 resources are damaged; and (6) selecting the appropriate defense response when system elements come under attack.

In the network concepts task, analyses and research also will be undertaken leading to the specification, design, development and verification of BM/C^3 networks. These concepts of C^3 network asset (computers and communications) management and their implementation in system software, will provide a high performance, fault-tolerant, secure and survivable C^3 network environment within which the battle management algorithms function. The

specification, design, development, verification and validation of alternative BM system topologies resource allocation/network asset management (or control) algorithms and network protocols will be pursued. Additionally, BM/C^3 system interface design, engineering and development of interface standards and configuration management guidelines will be accomplished.

Simulations will be used extensively to evaluate the many variables that come into play during the computer system design process. The simulations will be of a quality to serve as effective tools for the final design and development of the actual computer. Following the design and simulation tasks, a demonstration computer will be implemented to verify design specifications and to provide a real-time execution resource for fault-tolerant tasking and for executing critical BM algorithms.

In the fault-tolerant processors task, computer architectures, design methodologies and implementation technologies will be pursued to provide high availability, mission reliability and radiation survivability for complex battle management (BM) data processing systems onboard spacecraft or aircraft. The planned fault-tolerant research program will address: (1) definition of fault-causing phenomena at the component and system level; (2) development of fault-tolerant strategies, both in hardware and software; (3) incorporation of these strategies in computing architectures which will mitigate the effects of faults; and (4) development of capability to validate and trade between the many fault-tolerant alternatives for a given system environment. In addition, nuclear radiation upset/mitigation will be treated as a class of fault which has peculiar and far-reaching system survivability impacts. The research will continue several ongoing projects and from this nucleus form a more encompassing fault-tolerant program. Work in definition and development of special purpose architectures

such as dynamically reconfigurable computers and advanced distributed onboard processors will be used to gather data as to their effectiveness and to form the basis for a highly reliable architecture definition.

Research will include studies to define the SDI processing functions and fault-tolerant requirements that must be met, the information flow that exists between the functions and the response times needed to meet the overall mission response time requirements. The system operating concept definition and the requirements specifications derived from the need to do autonomous secure fail-safe processing will be developed. Promising architectural approaches will be incorporated in a demonstration computer to further validate usefulness and performance. Failures will be induced to observe the system response to failures. Hardware/software fixes will be designed, implemented and tested. The final products will include a fault-tolerant computer system specification for a system which will meet the BM requirements including those peculiar to the space environment and which reflect the capabilities demonstrated on the development model of the fault-tolerant computer.

In the communications task, research will pursue network planning and design, communication system designs and techniques, communication protocols and candidate communication network architectures, development of critical communications technologies and demonstration of the survivability of dynamic networks.

In the battle management software task, research has been structured to obtain high confidence of satisfying the BM software development support requirements. Near term activity will concentrate on upgrading and tailoring existing and planned software development technology to support the SDI SA/BM program. This approach will maximize use of evolving automated techniques (such as, Program Design Language) for requirements

specifications and analyses, program design and test. It will also permit integration with the DoD Defense Advanced Research Projects Agency high order language efforts, such as Ada, the DoD Software Technology for Adaptable Reliable systems program and other ongoing projects that are developing technology that may support part of the SDI BM software effort. The existing and evolving tools for definition of system requirements, software requirements, design and implementation efforts will be combined into an integrated framework that will increase productivity of and reduce errors in the BM software development process.

Emphasis will also be placed upon procedures which can verify the trustworthiness of the system being developed. These include software technologies for validating the effectiveness of the developed tools and techniques when used in realistic conditions. These new technologies include the use of design methodologies, rigorous inspection processes to provide correctness and analysis tools to measure correctness. Another major activity will be concerned with applying innovative and advanced concepts to BM software development. For example, knowledge-based engineering and expert systems technology may have great potential for improving the development process and will receive in-depth evaluation. Also modern supervisory/control software (systems) will be evaluated for their potential to achieve significant increases in efficiency and reliability. Advanced techniques will be integrated into the SDI BM software development technology base as their feasibility and usefulness are verified.

<u>BM/C^3 Experimental Systems</u>

<u>BM^3 Experimental Systems Technical Objectives</u>

The BM/C^3 Experimental Systems effort is one facet of the overall SDI strategy for technology verification that endeavors to provide the national leadership with the requisite technical information to decide whether to embark on development and/or

later deployment of a strategic defense system. The SDI technology verification strategy incorporates simulations, tests and demonstrations to evaluate the maturity of technologies required to support initial options for defensive systems. The performance of an SDI defense system will depend to a large extent on the performance of the Battle Management/C^3 system. Therefore, the architecture of the Battle Management/C^3 system must be developed as an integral part of the total defense system architecture.

The objective of this task is to define and develop experimental versions of Battle Management/C^3 architectures that would lead to BM/C^3 systems which will coordinate and control the functioning of the diverse defense elements to provide maximum defense effectiveness and reliability. The experimental versions of these architectures must demonstrate the ability to survive and operate reliably even in the presence of failures caused by nuclear effects, severe electromagnetic threat or direct enemy threats.

Significant Accomplishments (FY 1984-1985)

Emphasis was on an initial definition of alternative architectures for BM/C^3 and evaluating them according to identified quantitative subsystem functional and technical requirements and trade-offs. This work concentrated on space-based systems.

BM/C^3 Experimental Systems Project Description

The Battle Management/C^3 Experimental Systems project further develops BM/C^3 architectures, the resulting quantitative subsystem functional requirements, and technology tradeoffs, which are responsive to the BM/C^3 requirements identified as a result of SDI Systems Analysis. This project also performs the analyses and research leading to and including the development of experimental versions of BM/C^3 systems. The demonstration of these experimental versions will validate the

ability of technology to meet the requirements of the BM/C^3 component of a strategic defense. The BM/C^3 Experimental Systems research will use technologies selected from alternatives developed in the BM/C^3 Technology project assembled in experimental versions to evaluate system-level performance of technologies and architectural concepts.

The demonstration of experimental versions and the conduct of BM/C^3 experiments will be through the National Test Bed (NTB), where their execution in a system-wide simulated environment is required to assess the achievement of required technical performance. Where appropriate, stand-alone experiments may be conducted, which are remote from the NTB, to assess the performance of BM/C^3 technology.

The scope of the architecture is baselined on an SDI system to perform CONUS/Allied defense against ICBMs, SLBMs and IRBMs. Corollary self-defense missions will include those against lasers, jammers, spoofers, direct-ascent nuclear/non-nuclear and antisatellite threats, as well as threats to the terrestrial segments. The selected BM/C^3 architectures will establish performance requirements for supporting technologies in data processing and communications, for high confidence weapons release and safety and for system management and control algorithms.

Since the BM/C^3 technology required to support SDI systems is significantly more complex than previous programs in this area, early emphasis will be on identifying candidate BM/C^3 architectures, assessing technical performance and providing simulations to support engineering trade-offs among competing approaches. In order to incorporate realistic concepts of operation and weapon release procedures, inputs are expected from the Joint Chiefs of Staff and from field commanders.

For the BM/C^3 Experimental System project, computer facilities will be needed to support experiments to evaluate architectures and concepts to assess the performance of Battle Management/C^3 technology prior to the development of the National Test Bed and when stand-alone experiments are appropriate. Initial experiments will be undertaken as part of the incremental build-up to demonstrations of validated experimental versions of BM/C^3 systems in later years.

National Test Bed

National Test Bed Technical Objectives

The National Test Bed (NTB) project will define, develop, build and integrate a number of geographically distributed development, experiment, simulation and support facilities that are interoperable. Collectively these resources will provide the capability to demonstrate key defensive technologies and subsystems necessary to support a SDI full-scale engineering development decision in the early 1990s. The NTB will consist of a dedicated central National Test Facility (NTF) and other geographically distributed test and demonstration capabilities such as Service development and evaluation facilities, DoE National Laboratories and missile ranges. As an integrated set of resources the NTB will be a single national resource dedicated to the SDI and will provide the focus for the many SDI simulations, demonstrations and experimental activities.

Significant Accomplishments (FY 1984-1985)

This effort was initiated late in FY 1985. The NTB was conceptually defined to consist of a central NTF connected to, and interoperable with, other geographically distributed development test and support facilities that either presently exist or are developed under other program elements. The project's major tasks were defined to be: concept and requirements definition, design and development; construction of facilities (or conversion of existing facilities); integration; and operation of the NTB/NTF.

Military Uses of Space: 1946-1991

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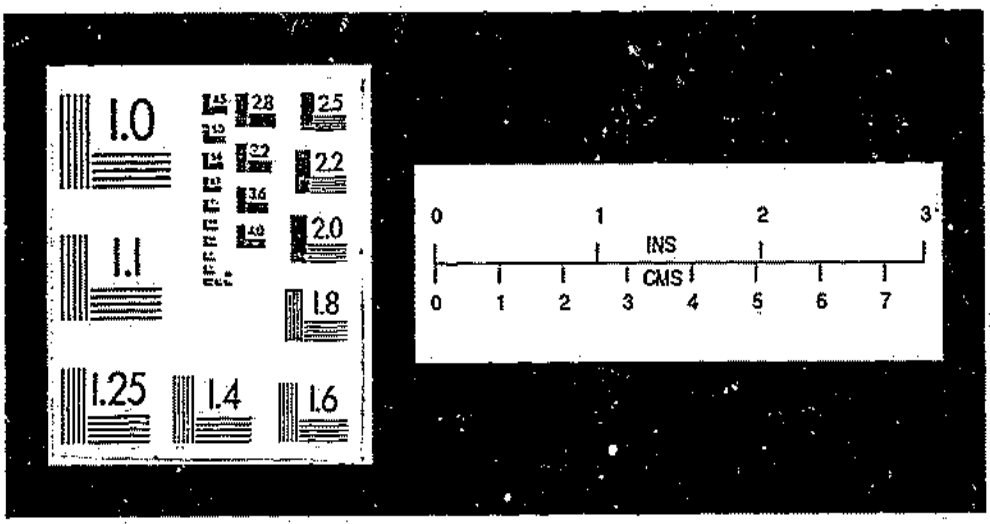

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National Test Bed Project Description

The NTB acquisition is envisioned as an evolutionary process, with subsystems and technology being developed and transferred into an initial capability at the National Test Facility.

The NTB/NTF will provide a capability of sufficient fidelity and extent to permit the comprehensive and specialized evaluation of alternative SDI systems and BM/C^3 technologies and architectures. It will be achieved through the use of flexible simulations and will include low-to-high fidelity algorithms and displays. Hardware-in-the-loop types also will be supported, including as a minimum, space-based, ground-based (including pop-up elements) and Allied anti-tactical ballistic missile architectures. Simulations of realistic threat scenarios and operational environments will support these architecture evaluations. The NTB/NTF also will provide the capability to support system and BM/C^3 experiments and tests from the minor subsystem level up through large-scale, realistic, system-wide, end-to-end experiments and demonstrations. Tests and demonstrations of generic and specific BM/C^3 technologies will be supported including networks, algorithms, processors, software engineering, communications, command and control and man-machine interfaces. Realistic interfaces, representative of system architecture components, that is, weapons and sensors, will be provided as needed.

The NTF will support the integration and control of interactive and stand-alone (autonomous) elements of experiments that will provide technology verification. The integration functions will involve hardware-in-the-loop operations with actual or replica subsystems, such as signal processors, communications controllers, message generators and also real or emulated interfaces with other SDI and non-SDI national or Allied assets.

Interim Assessment of Computing Requirements for BM/C^3 Technologies

In pursuing the BM/C^3 projects just described, computing and computational capabilities will be required to accomplish the following:

Networks:	Analysis of network configurations
	Analysis of algorithms for network operations
	Development of network concepts; evaluation using emulations of operating system software
Processors:	Support the design and verification of hardware SDI/space applications
	Circuit technology development and chip design
	Algorithmically specialized processors
Communications:	Analysis of communication system hardware requirements
	Research and development of transmission technology
Software:	Development of software engineering tools
	Evaluation of software engineering tools and environments
	Investigation of effect of massive computing power on software development and testing

F. SURVIVABILITY, LETHALITY AND KEY TECHNOLOGIES (SLKT) PROGRAM

Technical Objectives - The Role of SLKT in SDI

Important factors in deciding whether or not to develop and deploy a strategic defense must be effectiveness, affordability and survivability. The SLKT program performs research in key technologies that are critical to that decision. Specifically, it funds research to:

- Develop technologies and tactics to enhance the functional survivability of potential strategic defense force elements in hostile environments;
- Reduce major uncertainties that exist in the DoD's capability to predict the vulnerability of enemy targets that are responsively hardened to U.S. directed and kinetic energy kill mechanisms;
- Coordinate and stimulate the development of energy generation, conversion and power conditioning subsystems for deployed SDIO space and group systems;
- Develop the preliminary enabling technologies needed to improve significantly space logistics capabilities including transportation to orbit and repair and resupply on orbit; and
- Identify, coordinate, and manage high payoff research into the development of materials and large-scale structures that meets SDI-unique requirements.

The SLKT program element is organized into the following five projects: (1) System Survivability; (2) Lethality and Target Hardening; (3) Space Power and Power Conditioning; (4) Space Transportation and Support; and (5) Materials and Structures Development. A sixth project, Countermeasures, has been added to the SLKT program element in FY 1987 to support the work planned by the SDIO Countermeasures Office.

The System Survivability Project investigates concepts and technologies designed to assure defensive system functional survivability. The project is concerned with the system survivability for operational deployments of both initial strategic defenses and for follow-on defensive systems that are effective against a fully responsive defense suppression threat. The project is organized to: (1) assist the SDI Systems Architect in the development of candidate strategic defense architectures by ensuring survivability concerns are identified and addressed; (2) describe and update defense suppression threat descriptions to support survivability assessments; (3) investigate promising survivability concepts and initiate research into active and passive survivability technologies.

Survivability in its broadest interpretation means sufficient defenses remain to destroy the ballistic missile threat after dedicated attacks have been made to suppress the defense. It is a measure of how well the defense functions after an enemy attack and does not depend solely on the survival of the individual elements of the defense. Functional survivability is a combination of system requirements, tactics and technology. The project concentrates on providing the systems architect with survivability technology options, but will also perform some of the trade studies and analyses that will assess tactics as well.

The terms survivability, lethality and countermeasure refer to different phenomena. Lethality is concerned with the kill mechanisms to targets involving sophisticated techniques that may not produce dramatic results. Survivability, on the other hand, refers to the capability of being able to endure an attack ranging from attempts to degrade through attempts at outright destruction.

The term countermeasure as used here is defined as a specific response taken by the Soviets to negate the effectiveness of a defensive system. The countermeasure may be technical

(directed specifically against the hardware of the defense system) or tactical (designed to get around or overcome the effectiveness of the defenses). Political "counters" designed to prevent full deployment of the defensive system through outside means are addressed in Appendix A. It is important that all types of Soviet countermeasures be anticipated and addressed if the United States is to have sufficient information to make decisions regarding deployment of a strategic defensive system.

The Lethality and Target Hardening (L&TH) Project addresses the important issue of the precise effectiveness of any strategic defense. It is a project designed to perform comprehensive research, addressing such areas as effects damage and vulnerability of enemy targets caused by conceptual kinetic and directed energy weapons. The current tasks include the study of the effects of thermal/impulse/x-ray lasers, particle beams, kinetic energy projectiles, and high power microwaves on targets of interest. The effort includes a materials assessment program to ascertain theoretical hardening limits. The data, once developed, will provide performance requirements for the weapon system design teams.

Some weapon concepts being considered by the SDIO will require large amounts of electrical energy. There are projected unique requirements for the spaceborne concepts. Some research has been performed to produce power in large amounts, but none at the levels needed for these weapons concepts. While there is research on power that might be scaled to the needs of SDI, extensive research is still required.

The Power and Power Conditioning Project coordinates efforts to develop viable power generation and conditioning techniques capable of providing the large quantities of specially conditioned electrical power for space-based weapons, surveillance, communication, and battle management systems. The project requires funding in four tasks: (1) analysis and

assessment of power requirements and candidate concepts; (2) development of the SP-100 nuclear power subsystem for continuous power generation for SDIO, NASA and other agency needs; (3) the multimegawatt (MMW) evaluation of a broad spectrum of innovative concepts from industry and laboratories; and (4) pulse power conditioning to demonstrate the technical feasibility of performance as well as the feasibility of significant weight/volume reduction techniques.

The economic feasibility of a multitiered ballistic missile defense system against a fully responsive threat may well depend on the capability to deploy, supply and maintain such a system. The Space Transportation and Support Project funds the investigation of space logistics infrastructures, technologies and techniques to support an extensive space force of the magnitude and complexity envisioned by the SDIO. Areas to be investigated include, but are not limited to, heavy lift launch vehicles, orbit-to-orbit transfer systems, on-orbit assembly/servicing, robotics, reusable systems, advanced technology propulsion engine systems, avionics, and control systems. SDIO is a participant in the National Aerospace Plane research program.

Research is being conducted by DoD, DoE and NASA on materials and large structures to be used in space and on materials designed to increase the survivability of U.S. elements against natural and hostile environments. There is also research into structures requirements for various space systems concepts applicable to a strategic defense. There is emerging recognition of a need to concentrate the SDIO materials efforts into a single management project. This project, Materials and Structures Development, will be used to identify needs and initiate relevant research.

It has been widely recognized that in order for SDI system concepts to be credible to opponents and proponents alike, the concepts will have to be carefully and thoroughly examined by an

independent Red Team. The Countermeasures project supports a series of Red Teams to identify possible Soviet responses to SDI elements and to ensure that the implications of these responses are considered in the development process. The term "Red Team" is used here in a generic sense to indicate the sum of independent technological, political, military, and economic analyses that will be needed to conduct an independent review of a defense system concept and to identify credible potential Soviet responses. Red Team analyses are useful since they identify credible countermeasures to SDI systems and also those countermeasures that can be "ignored" because they are technically, politically, or economically infeasible. Both of these inputs are essential to the defense system designer. The first helps him to design a system which is robust to likely Soviet countermeasures; the second minimizes unproductive responses to threats that are not credible.

System Survivability

Description and Objectives

To ensure that the Systems Architect and hardware designers produce candidate strategic defenses that are capable of surviving to mission completion, the Survivability Project is structured to identify promising survivability approaches that include technologies, tactics and concepts. This project is expected to assure that promising approaches are evaluated for their effect on system performance and that trade-off assessments are conducted among the candidate survivability approaches. The results of the survivability technology, tactics and concepts research program will be provided to the Systems Architect and hardware designers for incorporation into candidate systems and the strategic defense architectures.

Significant Accomplishments (FY 1984-1985)

- An important accomplishment was the identification and transition, where appropriate, of relevant survivability activities to the SDIO. When the

System Survivability Project was initiated, there were a number of existing DoD Service and Agency research programs for ground system, airborne system, communication link, and space system survivability. Much of the research was related to SDI goals but was not oriented to meet the specific research objectives of the SDI. The criteria used to decide whether a task should be included in the System Survivability Project was that the proposed research be critical to an informed decision on the feasibility of candidate ballistic missile defenses. Additionally, the effort needed to have sufficient technical uncertainty so that research was warranted to try to reduce the risk to acceptable levels. Thus, a large part of FY 1985 was devoted to weeding out those technical programs that were of low risk and sorting out those efforts that were of interest only to a specific Service or Agency, but not critical to the SDI.

A reorientation of the survivability project also took place to balance research between near term survivability technial options and concepts that would meet far term objectives. The Systems Architecture will need to be able to handle the near term and evolve to handle the far term. The survivability research project is seeking to provide the correct balance so that the necessary technical concepts are available at the right time.

Initial research in survivability technologies has already produced promising concepts and designs for several areas. A multiyear technology development and test program was developed to support system definition efforts. Technical requirements and concept studies initiated in FY 1984 were completed and have established the role some technologies

will play in strategic defense systems. The design and development of experimental testing of hardening techniques began in FY 1985 and have indicated a need to progress to more sophisticated testing.

- The capability to harden electronic components and subsystems from the effects of a nuclear environment has achieved substantial progress. Results from planned testing met or exceeded all specifications. The required technology base to establish the viability of some circuits to provide extremely hard electronics has made excellent progress. Additionally, numerous tests and analyses have been performed on some new microelectronic technologies. This will ensure timely development and evaluation of alternate and innovative microcircuit technologies.
- Several devices to protect electronics from System Generated Electromagnetic Pulse (SGEMP) surge currents have been developed and tested with design methodology confirmed.
- A technique for hardening optical surfaces from the effects of nuclear radiation is being developed. Preliminary conclusions indicate the capability to attain hardness levels substantially above current state-of-the-art.
- Initial testing of the effects of some radio waves on generic electronics has established preliminary interference effects thresholds, increased the understanding of coupling effects, and advanced the development of hardening strategies.
- There has been an initial compiling of detailed threat scenarios describing possible responses an adversary may take against U.S. strategic defenses. This threat task was undertaken originally within

the System Survivability Project. The first Defense Suppression Threat (DST) document was published in FY 1986.

Lethality and Target Hardening

Description and Objectives

The objective of this project is to determine the lethality that can be inflicted by the type of weapons being considered in SDIO research on the full spectrum of targets that a U.S. strategic defense may encounter. Project experimental research is expected to validate theoretical models that predict lethality against the hardened and unhardened targets against which the U.S. defense would be employed. Testing is being conducted on both subscale and full-scale models. The resultant data on the induced structural response and target failure modes are of fundamental significance in assessing the potential of proposed SDI weapon concepts.

The Lethality and Target Hardening Project is heavily oriented toward the generation of basic scientific data. The High Energy Laser System Test Facility (HELSTF) is being used to assess booster vulnerability to high intensity continuous wave thermal lasers. A particle beam test facility for the generation of a particle beam target effects data base has also been developed and will become operational in FY 1986 at Brookhaven National Laboratory. Kinetic energy projectile research will establish a basis for determining hit-to-kill lethality levels and will increase our understanding of layered and composite material response to hypervelocity penetrators.

SDIO expects to develop hardening techniques and incorporate them into system testing for evaluation with respect to performance, mission impact, cost and maintainability. To assure maximum cooperation and use of available resources, all SDI Lethality and Target Hardening efforts are being closely coordinated with complementary weapon research efforts in the

Department of Energy. Because the lethality project establishes failure levels, much of the data could be useful for survivability assessments. Efforts are, therefore, carefully coordinated between this project and the System Survivability Project.

Significant Accomplishments (FY 1984-1985)

The Lethality and Target Hardening Project has achieved the most progress among the SLKT projects. For a number of years, various Service and Agency programs had supported limited examinations of vulnerability and target hardness issues for particular applications. Portions of these programs were integrated into the SDI lethality project. In addition:

- Continuous wave laser tests were conducted at HELSTF on full-scale solid and liquid boosters under simulated flight loads. (See Figure VII.F.1).
- Impact tests with kinetic energy projectiles at velocities up to 8 km/sec were performed. The quarter scale test fired an 18 gm fragment at both a post-boost vehicle (with RVs) and a liquid fueled target. (See Figure VII.F.2 and VII.F.3). Significant issues associated with this PBV kill are being assessed. The modification of a gas gun test bed will permit testing at 10 km/sec in FY 1986. Development of an electromagnetic accelerator test bed was initiated at Los Alamos National Laboratory. Testing at hypervelocities (15 km/sec) will begin in FY 1987.
- Construction was initiated on a dedicated particle beam lethality test bed at Brookhaven National Laboratory to be finished in FY 1986.
- Modification of a large excimer laser at Los Alamos National Laboratory was completed to permit high fluence tests in FY 1986.

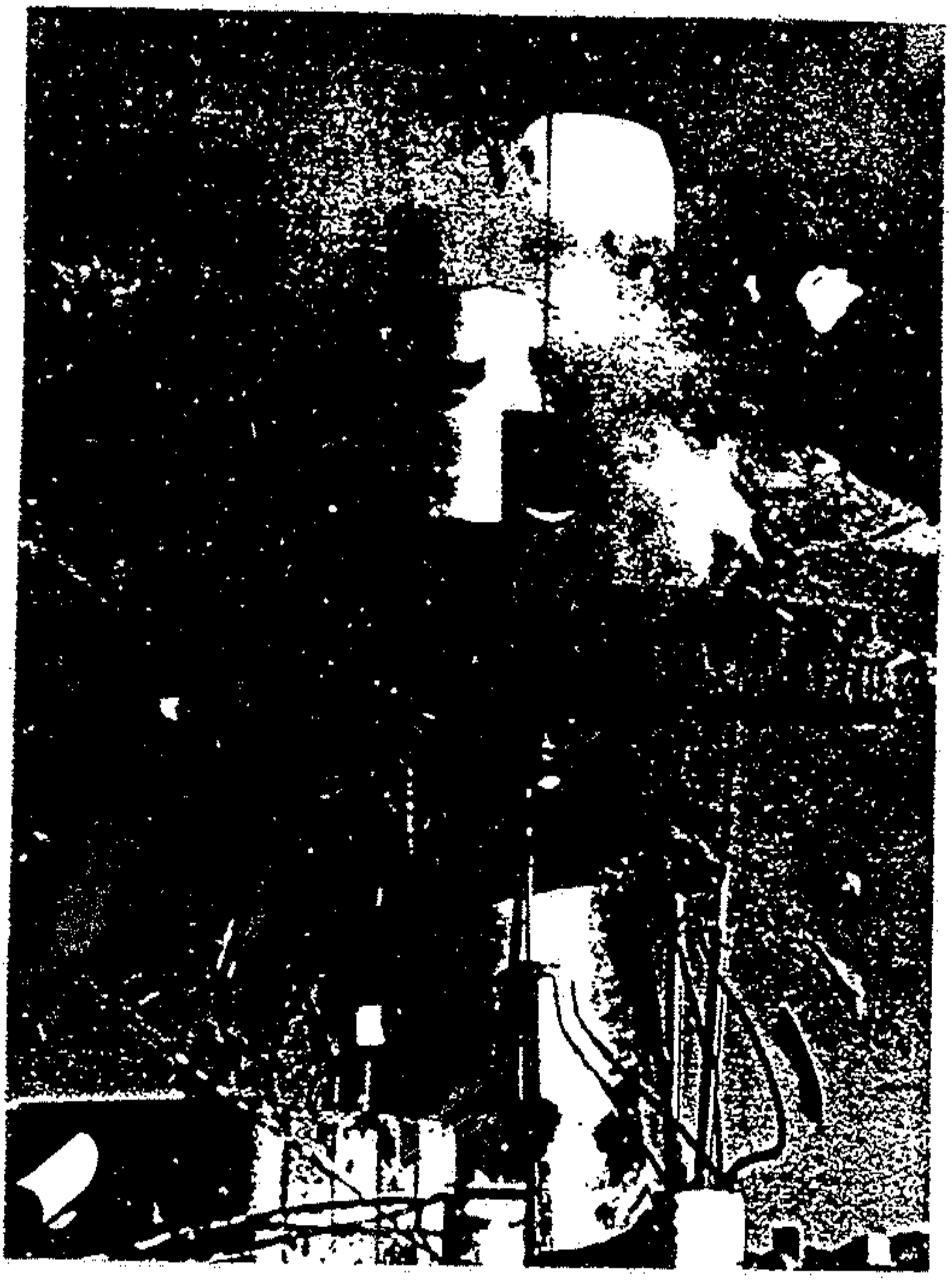

Figure VII.F.1. A Booster Body Section Being Destroyed in a Test Using a Continuous Wave Laser

Figure VII.F.2. Actual Damage to Reentry Vehicles (Kinetic Energy Fragments)

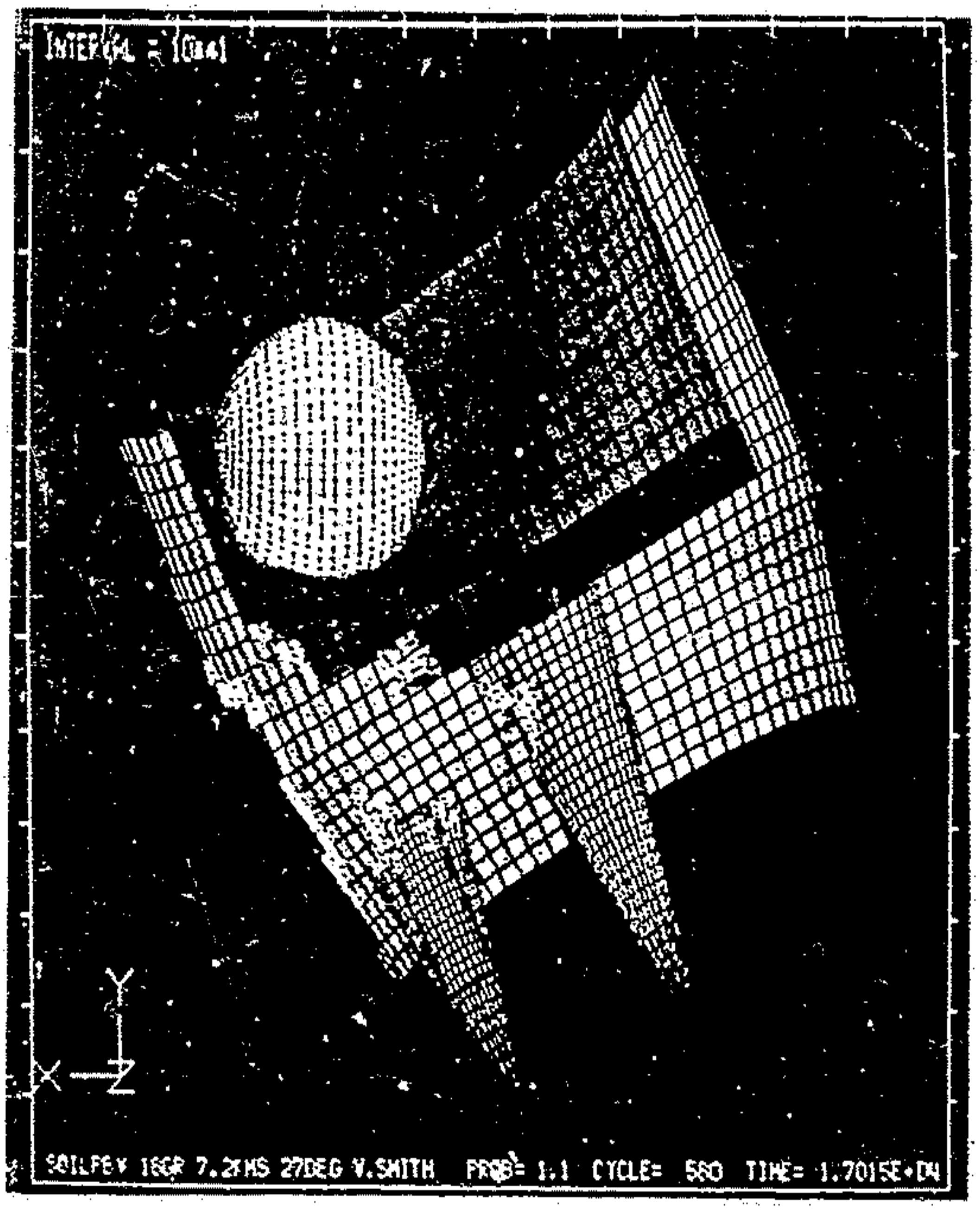

Figure VII.F.3. Computer Prediction of RV Damage
(Excellent Match to Actual Damage)

Power and Power Conditioning

Description and Objectives

Among the findings of the Fletcher Study was the conclusion that the overall success of certain concepts is highly dependent upon the ability to generate tremendous amounts of electrical power. In response to this challenge, the Power and Power Conditioning Project was established to develop power generation and conditioning technologies capable of providing electric power for the projected needs of a strategic defense. Power levels in excess of 100's of megawatts have already been identified. The program consists of four tasks: assessment and analysis of power subsystem concepts and requirements; the joint SDIO/NASA/DoE SP-100 task; multimegawatt (MMW) power research; and pulsed power technology conditioning development.

The Assessment and Analysis task includes the power requirements definition and mission integration studies, power system architecture studies, and the assessment and evalution of candidate concepts. A requirements document containing a comprehensive set of specific power requirements based upon the system architecture studies is being generated. The document will be updated annually as the system concepts evolve. The power system architecture studies will investigate the effects of the natural and system-generated environments on the power subsystem, and the interactions between the power subsystem and the other subsystems comprising the candidate space platform. To support Power and Power Conditioning efforts, an Independent Evaluation Group (IEG) was formed. The purpose of the IEG is to advise the SDIO on the technical merit, trade-offs and technology needs of proposed concepts, to identify and track the evolving power subsystem requirements through coordination with other program elements under the SDIO, and to provide power subsystem analysis and models to support SDI System Architecture activities.

The SP-100 task represents an intermediate stage of development for high power space-based systems. SP-100 is the cornerstone of the research and technology effort seeking long term continuous power supplies (see Figure VII.F.4). It is a 100 kilowatt-class nuclear power generation subsystem that will have the potential for growth up to the 1 megawatt level. The task is funded jointly by the SDIO, NASA, and DoE. This technology is needed not only to provide moderate continuous power levels for a variety of projected SDIO needs, but also to act as an enabling technology for several NASA and non-SDIO military programs under consideration for the 1990s. The major subsystems (reactor, power conversion, heat transport and radiator, and control) will be ground tested as part of Phase II. A reference mission that combines the SP-100 with electric propulsion is targeted for a FY 1993 launch.

The multimegawatt research task was initiated in FY 1985 to address the projected SDIO requirements for both high level continuous power and burst mode power. The goal is to establish and advance the technology base sufficiently by the early 1990s to establish the feasibility of satisfying mission requirements within acceptable costs. Both nuclear and non-nuclear power sources are under consideration in open cycle and closed cycle configurations. The overall task strategy is to solicit and evaluate a broad spectrum of candidate concepts from industry and laboratories, followed by a narrowing of the number of potential concepts during FY 1986, and then to embark upon both generic and concept specific technology development. A further narrowing of the number of concepts is expected to occur in FY 1988, with focus placed upon the primary technology efforts in support of the candidate concepts. Ultimately, efforts would continue to develop the data base for these concepts in order to establish overall feasibility.

A new start in FY 1986, the Pulsed Power Conditioning Technology task, addresses the special energy forms and

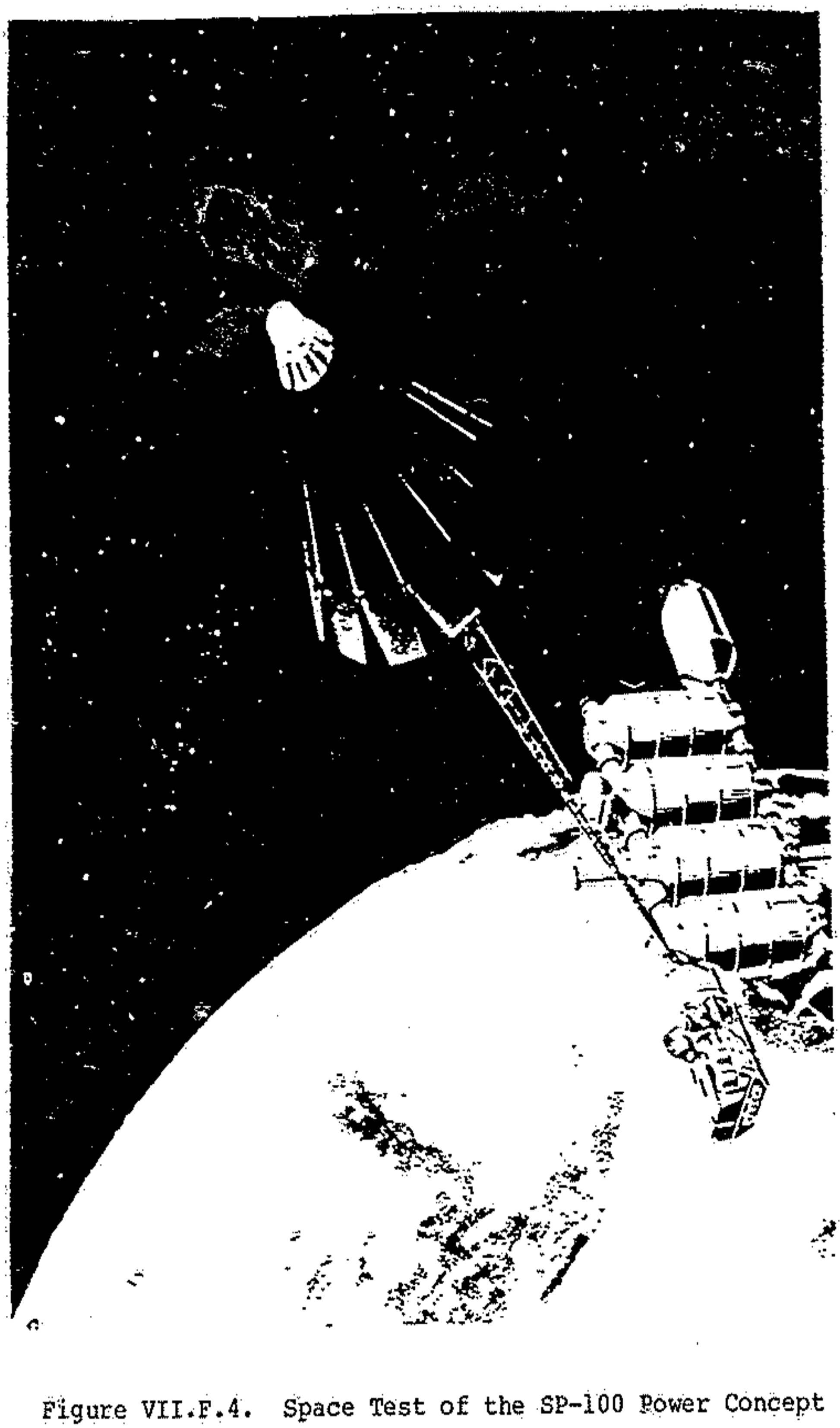

Figure VII.F.4. Space Test of the SP-100 Power Concept

delivery requirements for the weapons systems. It is a broad-based effort that seeks to expand the existing technology base through fundamental research and development with emphasis on critical element development. Pulsed power technology is the set of technologies used to condition raw power generated from prime power sources to match the electrical requirements of a given load. Critical pulsed power elements include RF sources, switches, intermediate energy stores, and power distribution elements. The effort will seek to develop elements capable of delivering sufficient energy pulses to drive the proposed weapons concepts.

Significant Accomplishments (FY 1984-1985)

- Under Assessment and Analysis, the first draft of the requirements document is complete, and the request for proposals for the Power System Architecture studies was issued.
- The SP-100 project is proceeding on schedule and has successfully transitioned from Phase I, Technology and Assessment, to Phase II, Ground Engineering Development Testing. Phase I culminated with the selection of the liquid-metal-cooled fast spectrum reactor and the thermoelectric power conversion option. The Hanford Engineering Development Laboratory has been selected as the preferred test site for the reactor test. Phase II involves developing and demonstrating the performance, safety, dependability, manufacturability and technology readiness of the selected power system concept through ground testing of the major subsystems at appropriate test facilities. Critical component testing will occur during FY 1986 and FY 1987. The final design will be completed in FY 1988 and ground testing will be completed in FY 1991.

- FY 1985 was primarily a planning year for the multi-megawatt task. Major accomplishments included the establishment of the MMW management structure and formation of the IEG. In addition, responses from the solicitation of advanced concepts from industry and laboratories for MMW subsystems and components were reviewed and screened.

Space Transportation and Support

Description and Objectives

The Space Transportation and Support Project funds both research to understand strategic defense system requirements from a logistics and maintenance perspective and the development of technology to significantly reduce costs of space operations. This project seeks to identify the transportation and servicing requirements sufficient to deploy and maintain a robust and effective strategic defense; focus research efforts on promising technologies and concepts; and construct a body of knowledge which will contribute to making an informed decision regarding system development. It is clear that there is not now an adequate knowledge of the supply requirements and logistics infrastructure to support a space force of the magnitude and complexity envisioned for a multitiered ballistic missile defense.

Significant Accomplishments (FY 1984-1985)

- The approach to organizing, managing and funding the Space Transportation and Support Project has been formulated.

- Multi-agency National Space Transportation Architecture Studies were begun to investigate military and non-military space transportation requirements for the 1990s and in the post-2005 timeframe under the direction of a National Security Study Directive.

- Transportation Technology Team organized to propose, manage, and direct technology programs to focus on the objective of reducing the costs of space operations.

Materials and Structures

Description and Objectives

In the Fletcher Study, and early on in the SDIO research program, there was an implicit need for concomitant research and development of materials and large space structures. Several systems and critical technologies could not succeed if there were not parallel discoveries and improvements in this area. For instance, major lightweight platforms for use in space would depend on employment and maintenance of large structures not yet built and tested for space use. It was also recognized that materials and structures do not now exist for the degree of survivability required by a strategic defense.

At the onset, it was believed that such technology could be brought along in association with existing projects, but it has become increasingly clear that individual activities could be more corporately productive through concerted coordination and with better focus on those activities through central management. Also, there appears to be a wide number of onging research efforts that could be more beneficial to the SDIO if technology managers outside the SDIO could be encouraged to work also toward the SDIO objectives.

While there are fundamental critical requirements toward which the SDIO must work, the area of materials and large space structures is one where the end users would especially benefit by innovation and improvement over and above the basic requirements. Gains in materials hardness against enemy weapons is one example of a critical survivability technology whose payoff continues regardless of the level of increased investment.

Another example is inexpensive production of lighter weight optics. It is increasingly apparent that a large number of these requirements in the SDIO can be identified and assisted through this project.

Significant Accomplishments (FY 1984-1985)

- Limited research activities investigating materials and large structures for transport, operation and survivability in space (funded under Project 0010, System Survivability and other SDIO Program Elements) indicated this technology area lags behind other efforts within the SDI. Based on this, it was decided to consolidate and/or expand current materials and large structures work.
- Initiated an assessment to determine the generic materials and large structures requirements within the SDI research program and to identify ongoing projects both within the SDIO and elsewhere that are relevant to the Materials and Structures Project.

Countermeasures

Description and Objectives

The principal elements of the SDI countermeasures analyses program are (1) a Soviet Red Team, (2) Technical Red and Blue Teams, and (3) Mediators. The major objective of the Soviet Red Team is to formulate a reasonable Soviet global response to a strategic defense. This team will generate a "top-down" set of Soviet priorities for countering the SDI program (which may not coincide with the current emphasis in the SDI technical programs). For example, the Soviet Red Team may determine that the most likely Soviet response to an SDI system concept is to build a class of weapons that circumvents rather than counters the U.S. defense. The Soviet Red Team

will also interact strongly with the Technical Red Teams and assist them in determining probable Soviet priorities for various technical counters.

The Technical Red Teams will be organized as necessary to continue and greatly expand the technical countermeasure analyses conducted to date. They will examine system concepts (boost and midcourse defense concepts, for example) or individual components of a system concept to assist the defense designers in understanding technical responses to their system or component. Each Technical Red Team will interact with a corresponding Blue Team formed by the defense system proponent in coordination with the appropriate SDIO Program Element Director. The Blue Teams will assess the impact of the Red Team analyses on their system design and make appropriate responses to the Red Team.

The iterative process beween the Red and Blue Teams will be facilitated by a set of Mediators. The Mediators are a group of senior government and industry people who are experienced in strategic offense and defense and can rapidly review the results of red and blue analyses to determine credibility, assess implications on SDI system concepts or components, and provide sound advice for further analyses. The Mediators report directly to the SDIO Chief Scientist. It is this group that ensures that the analyses are conducted properly and that the implications developed are reasonable. The Mediators formulate recommendations for the Director, SDIO.

Also included in the Countermeasures Project is an experimental program. Here possible countermeasures will be built and tested if it is necessary to determine if a countermeasure proposed by a Red Team and found to be technically feasible by the Mediators will actually work as conceived. The experimental work could be conducted by either industry or government agencies.

Significant Accomplishments (FY 1984-1985)

- Established and staffed an independent office reporting to the Director within the SDIO to manage a continuing program for countermeasures analysis, to identify possible Soviet responses to the SDI and to ensure these responses are addressed by SDI systems designers. The Countermeasures Project began at a very low level in the last half of FY 1985.

- Established Technical Red and Blue Teams to consider the design of the High Endoatmospheric Defense System being developed by the Army. Preliminary results are expected in early FY 1986.

- The Soviet Red Team was established and commenced work formulating reasonable global Soviet reactions to the SDI. This activity adds political and economic considerations to the analysis performed by the Technical Red Team.

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G. INNOVATIVE SCIENCE AND TECHNOLOGY (IST) OFFICE

Description and Objectives

The Innovative Science and Technology (IST) Office is a technical division within the SDIO. IST has the task of seeking new and innovative approaches to ballistic missile defense. It allocates funding to sponsor research in innovative approaches and assures that other technical divisions within the SDIO are informed of new results and breakthroughs from IST programs.

The IST Office has several specific roles. First, it establishes a technology base for strategic defense through fundamental research. This kind of research effort is conducted throughout the scientific community in universities, government and national laboratories, small businesses, and large industries. Second, the IST Office provides a window for the scientific community into SDIO programs. This unobstructed view is very important since many of the new ideas and breakthroughs in basic science and engineering have been spawned traditionally from university programs. Many of the basic ideas on which SDIO success may depend may also come from those same universities. Finally, the IST Office has the responsibility to administer the SDIO Small Business Innovation Research (SBIR) Program. This federally-mandated program required in FY 1985 that 0.5 percent of the total SDIO extramural Research & Development funding be allocated to small businesses via the SBIR mechanism. This requirement increases to 1.0 percent in FY 1986.

The IST Office sponsors fundamental research programs in six major areas: (1) advanced high-speed computing, (2) materials and structures for space applications, (3) sensing and discrimination, (4) advanced space power, (5) space sciences and experimentation, and (6) directed/kinetic energy concepts. The research program is centrally managed by IST personnel and implemented though Science and Technology Agents (STAs) located at other government agencies (such as Office of Naval Research, Air Force Office of Scientific Research, Army Research Office,

Defense Nuclear Agency, NASA, DoE, and other DoD laboratories). Proposal review, contracting, and day-to-day technical management of the IST research programs are the responsibility of the STA.

Significant Accomplishments (FY 1984-1985)

SDIO's Innovative Science and Technology research program has been in existence for less than one full year. Nevertheless, a number of significant accomplishments have occurred since its commencement. Ongoing projects have been accelerated by IST funding, or new projects have been initiated by IST. Some of the best examples of these are:

- A new composite material, lithium alumina silicate glass reinforced with silicon carbide fibers, has been recently fabricated. This new material combines its amazing lightweight, laser-resistant properties with very large tensile strength, making it very promising for space structure applications.
- A new insulating polymer, made from resins of vinylidene fluoride and tetrafluoroethylene, has been designed totally via computer simulation and then synthesized in the laboratory. This new polymer will be used in the construction of new high-energy density, super capacitors.
- The first generation of novel super-capacitors for power storage has been designed and constructed. These capacitors can store up to 50 kilojoules of energy in a can the size of a large wastebasket. Such devices could have a large number of applications in many of the directed and kinetic energy concepts being explored by SDIO.
- As part of the high-speed computing effort sponsored by the IST, a program exists in optical data processing. A major breakthrough has occurred in the effort to construct an optical supercomputer--the development of an optical, bistable switch.

While this occurred overseas, the institution responsible for this breakthrough is eager to join the IST program in this area and cooperate with American researchers on this project.

- A major program exists at the Lawrence Livermore National Laboratory to develop a laboratory x-ray laser. Although initial experimental success in this program was realized in 1984, no theoretical explanation was forthcoming until IST funded a program to investigate the phenomenon. In less than 6 months, the new project produced an explanation for the new lasing scheme and substantiated the result with computer simulations.

- A new ultra-high energy density mini-capacitor has been developed by the IST space power consortium, with 1.0 microfarad storage capacity at 5.5 volts in a container of only 15 cubic centimeters. The idea is based on maximizing the ratio of conductor area to separation distance using activated carbon, which has an amazing surface area of 500-1000 square meters per cubic centimeter of particles.

- A new micro-miniature refrigerator the size of a quarter has been developed that can cool to 10 degrees Kelvin a niobium nitride superconductor used in Germanium infrared detectors for the SDIO sensors mission. The refrigerator fluent is pumped by a novel nonmechanical pump that could be powered from the heat extracted by exhaust in a space system.

- A major breakthrough was achieved in the area of Mossbauer spectroscopy when an IST researcher found that he could compensate for the recoil of the nucleus caused by gamma ray emission by employing an external laser as an additional photon source to enhance the energy of the gamma ray via "dressed"

isomeric levels. This is the first step toward the development of an effective gamma ray laser.

Current Activities and Future Plans

In the coming months, the Innovative Science and Technology Office anticipates that many of the accomplishments listed above could be implemented in ongoing IST-sponsored projects.

In the area of electromagnetic launcher systems, a new technology test bed to be used for lethality, materials, dielectric and insulator research, and other key issues is to be completed soon. The operating specifications of this system will be to accelerate 100 gram projectiles to velocities of 5 km/sec with a duty cycle of at least 20 shots per week. This program should do much to alleviate the stark lack of data in the electromagnetic launcher data base, as well as to serve as a test bed for new rail materials and insulators.

The super-capacitor program described above is aimed at extending the frontier in capacitor design to produce a device that stores 250 kilojoules of energy in the same size can as the existing 50 kJ capacitor. In three years, the goal is to store a megajoule of energy in this volume. If this goal is attained, the well-known and reliable technology of capacitors begins to compete with much more complex schemes for economic power storage in space.

The program in metal-matrix composites has recently become interested in using these materials for large mirror fabrication. The implication for the robust optics requirements of the SDI is far-reaching: better uniformity, more survivable, more easily machined, and more lightweight than conventional optics.

The miniature cryogenic cooler described above is to be used in the fabrication of a novel, low-cost, broad-band, infrared detector. These detectors are needed to perform the many sensing tasks required by a strategic defense system, and the development of new miniature devices with very low power requirements will greatly assist in the performance of this mission.

The IST Space Nuclear Power Consortium has, in addition to other schemes, a plan to design a multi-megawatt pulsed gaseous fuel reactor. The advantage of a gas fueled reactor concept is that the gas can be pulsed rapidly throughout the system to attain the burst-mode power requirements needed for many directed and kinetic energy concepts being explored by SDIO. The consortium is also studying the maintainability, reliability, and safety issues associated with such a reactor in concert with the design program.

In the area of directed energy, the study of novel schemes for designing a gamma ray laser has been bolstered by the recent result in Mossbauer spectroscopy. Although this is still a far term effort, the potential for success is quite high and would result in storage of energy in a directed energy beam that would exceed the present SDIO requirements by several orders-of-magnitude. An added attraction of the existing gamma ray laser schemes being investigated is that they do not depend on a nuclear explosive driver to pump the laser.

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CHAPTER VIII
ORGANIZATION AND RESOURCE MANAGEMENT

A. ORGANIZATIONAL STRUCTURE AND RESPONSIBILITIES

The SDIO is an independent defense agency. The Director, Strategic Defense Initiative Organization (DSDIO), reports directly to the Secretary of Defense. The organizational structure, designed to assist the DSDIO, consists of both technical and administrative offices. These offices address ongoing scientific research, broad policy issues in conjunction with the Under Secretary of Defense (Policy), and the efficient management of people and resources. Figure VIII.1 displays the current organizational scheme for the SDIO. From an austere beginning in FY 1985, an office staffed by eight military personnel and four civilians, the SDIO has increased to 51 military personnel and 49 civilians by the end of that fiscal year. Due to the critical nature of the SDI research program, the selection of SDIO personnel focuses on highly competent technical, policy and resource management people.

Effective SDIO management of the SDI research and technology program requires guidance to, and careful coordination with, various participating and interested organizations. This includes, but is not limited to, the following organizations: Army Strategic Defense Command, Headquarters U.S. Air Force, Defense Nuclear Agency (DNA), Department of Energy (DOE), various National laboratories and numerous civilian contractors. The efficient use of resources requires that ongoing coordination exist between the SDIO and non-SDI programs performing SDI-related research. For example, innovative technologies such as the strategic computing program developed in the Defense Advanced Research Projects Agency (DARPA) and Air Force anti-satellite research efforts address areas of interest to the SDIO. Finally, national policy questions require effective coordination between DoD, the State Department, the Congress and administration officials.

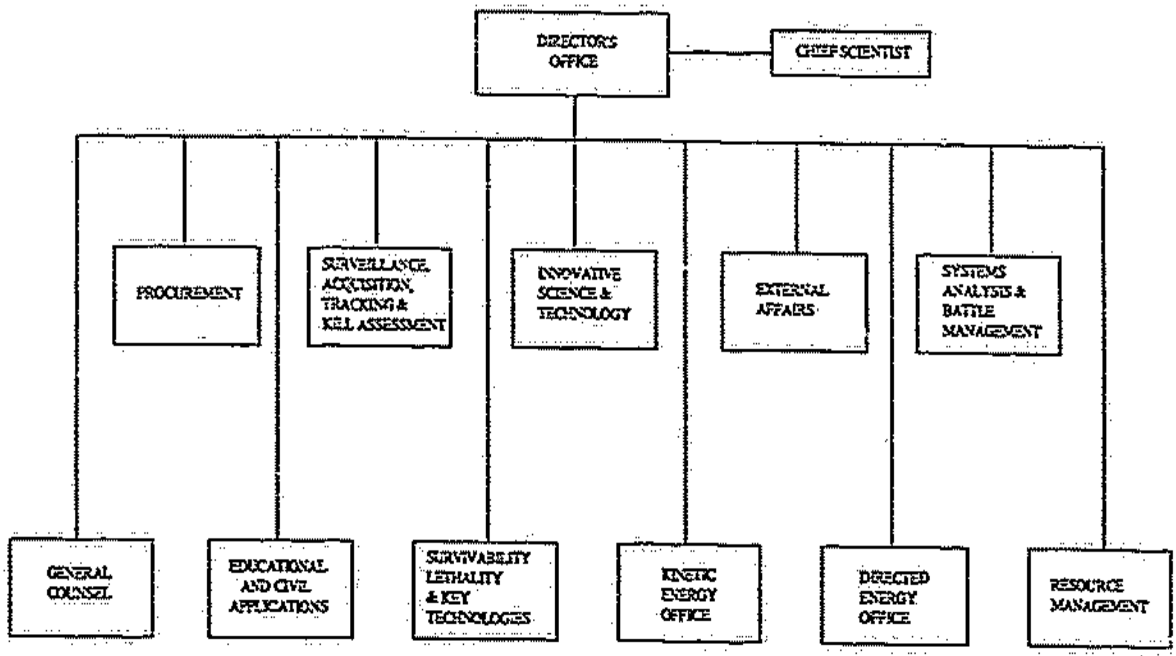

Figure VIII.1. The Current Organizational Structure of the SDIO

The DSDIO is responsible to the Secretary of Defense for coordinating and executing the SDI program within the Planning, Programming and Budgeting System (PPBS). The DSDIO represents the SDI program as a member of the Defense Resources Board (DRB) when strategic defense or related matters are under consideration. The DSDIO is also responsible for submitting the inputs from the SDI program PPBS to the Director, Program Analysis and Evaluation. It is the DSDIO who defends the SDI program and its budget before Congress. Where required, the DSDIO also initiates actions to reprogram SDI activities in accordance with DoD Directives and Federal Law.

B. SIGNIFICANT ACCOMPLISHMENTS (FY 1985)

The SDIO made significant progress in the past year. It centralized the planning and control of the SDI program while decentralizing the execution of specific technology efforts. In doing this, achievements in efficient program management and resource management are particularly noteworthy.

Much program activity in early FY 1985 was a transition of existing research activities from DoD services and agencies to the SDIO. New program starts were initiated, and many existing programs were altered to focus research efforts on SDI goals and technical objectives. The SDIO further ensured stringent use of funds for productive results.

The SDIO effectively managed funds during this transition period although there were problems typical of startup activities and large program growth. Obligation rates for FY 1985 were very high. Expenditures were comparable to similar DoD research activities such as the Defense Advanced Research Projects Agency and the Air Force Research and Development (R&D) effort. Approximately 1,000 SDI contracts were awarded during FY 1985. By the end of the year, the majority of FY 1985 work had been completed. Program and resource management accomplishments include:

- Obligation rates in FY 1985 of 94 percent. Table VIII.1 shows comparisons of obligations and expenditures in several areas of the DoD which are comparable to SDIO. Although these multi-year funds were available for obligation during FY 1985 and FY 1986, the SDIO's obligations were consistently higher than comparable research programs. The SDIO managed to attain normal expenditure rates despite normal startup activities and large program growth.

- Over 90 percent of FY 1985 work was completed by year's end. Approximately 1,000 contracts were executed.

- The SDIO established centralized planning and control of the overall program. A review by the General Accounting Office (GAO) regarding the SDIO's FY 1985 obligations and program plan was positive in its findings.

C. <u>CURRENT ACTIVITIES AND FUTURE PLANS</u>

Table VIII.2 shows by program element the appropriations for FY 1985, the appropriations for FY 1986 and the President's Budget for FY 1987. Figure VIII.2 indicates the status of SDI funds for FY 1985.

The FY 1986 funding plan includes $2.35 billion in existing contracts started in FY 1985. A significant portion of this SDIO effort was initiated in late FY 1985 after the SDI was restructured to accommodate the FY 1985 Congressional cut of $1.0 billion.

The SDIO expects participating organizations to execute more than 1,000 contracts during FY 1986. Most of these contracts primarily involve technical research in six technical areas. SDIO is seeking considerable growth in the FY 1987

TABLE VIII.1

FISCAL OBLIGATION AND EXPENDITURE COMPARISONS WITHIN DoD

OBLIGATIONS (%)

	ANN PGM	MAR	APR	MAY	JUN	JUL	AUG	SEP
TOTAL ARMY R&D	$ 4.4B	53	59	64	69	75	79	89
TOTAL NAVY R&D	$ 9.3B	70	75	80	84	86	89	93
TOTAL AF R&D	$13.5B	51	58	62	66	71	76	87
SDIO	$ 1.4B	56	62	66	70	76	83	94
DARPA	$ 0.7B	44	51	57	66	72	76	84
AF STRAT R&D	$ 5.7B	44	51	58	60	64	68	85

EXPENDITURES (%)

	ANN PGM	MAR	APR	MAY	JUN	JUL	AUG	SEP
TOTAL ARMY R&D	$ 4.4B	18	23	27	32	38	44	50
TOTAL NAVY R&D	$ 9.3B	14	19	23	33	39	44	51
TOTAL AF R&D	$13.5B	17	21	26	30	35	40	45
SDIO	$ 1.4B	9	12	16	21	27	34	40
DARPA	$ 0.7B	3	5	8	20	25	29	42
AF STRAT R&D	$ 5.7B	10	15	19	21	26	30	34

TABLE VIII.2

SDIO APPROPRIATIONS AND FUNDING REQUESTS, FY 1985-1988 ($M)

	FY 1985	FY 1986	FY 1987	FY 1988
RDT&E				
SATKA	545.950	856.956	1262.413	1558.279
DEW	377.599	844.401	1614.955	1582.037
KEW	255.950	595.802	991.214	1217.226
SYSTEMS	100.280	227.339	462.206	563.998
SLKT	108.400	221.602	454.367	523.654
MGMT HQ	9.120	13.122	17.411	18.118
TOTAL RDT&E	1397.299	2759.222	4802.566	5463.312
MILCON				
TOTAL CONSTRUCTION	0.000	0.000	10.300	48.147
TOTAL	1397.299	2759.222	4812.866	5511.459

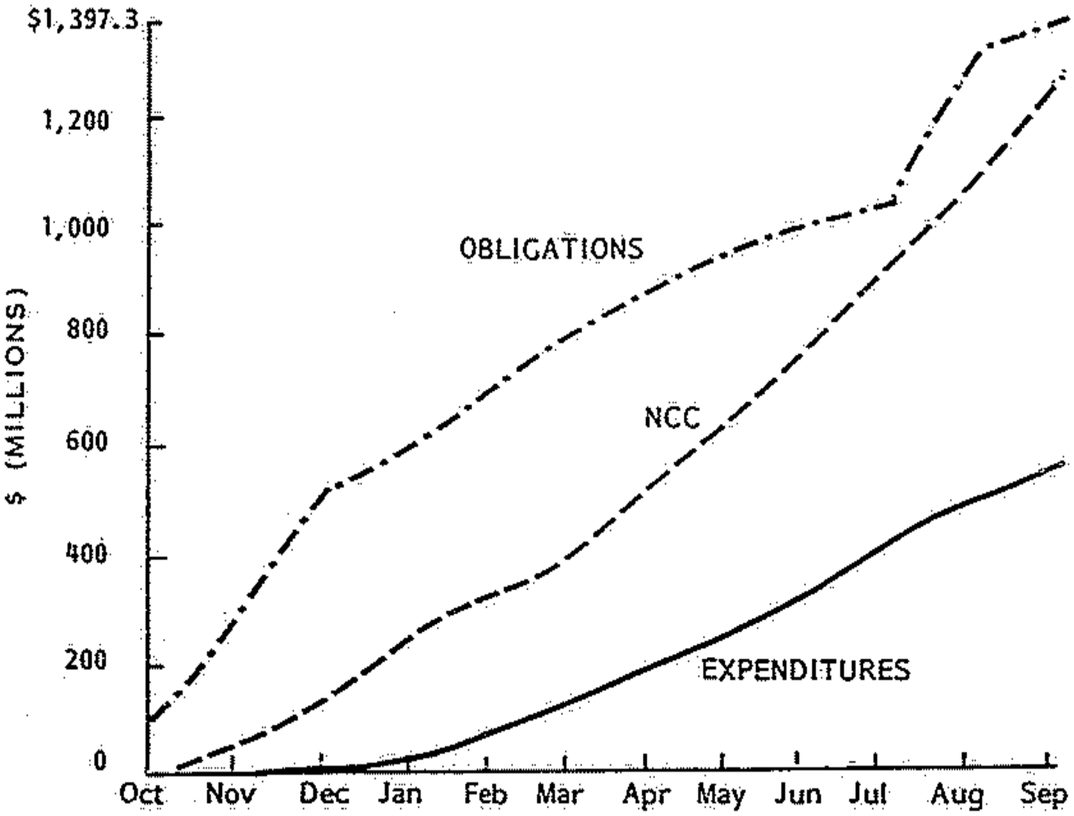

Figure VIII.2. Status of Strategic Defense Initiative Funds for FY 1985

funding plan because technologies comprising the SDIO program are now ready for evaluation and emphasis. This phenomenon of large annual growth is common when emerging technologies have undergone low-level research and are ready for applications to potential weapon system concepts. In this growing effort, the SDIO goal has not changed since the President's March 1983 speech. The SDIO plans to continue vital ongoing efforts in the FY 1987 SDI program. The FY 1986 SDIO fiscal projection includes a 95 percent obligation rate, a 90 percent noncancellable commitment rate and a 60 percent expenditure rate (Figure VIII.3).

Many U.S. Allies support SDI research and some have shown interest in participating. U.S. and Allied security is indivisible. Work will continue closely with the Allies to ensure that Allied views, capabilities and resources are carefully considered. In addition to direct work for the program, potential contributions by Allies include innovative university research, individual exchanges, subcontracts to U.S. industry or associate contractor arrangements.

One aim of the SDIO is to put resources to their most productive use. The SDIO maintains that the traditional milestones of obligations and expenditures are important, but inadequate. Obligations generally occur when contracts are awarded and indicate only that work can begin. Expenditures reflect only payments and the data is recorded months after the work has been accomplished. Both of these financial tools fail to reflect the true measurement of actual SDI work accomplished.

Because of these factors, the SDIO now measures work accomplished to date by means of noncancellable commitments (NCC). This is a method to determine what has actually been accomplished by estimating government liability to date.

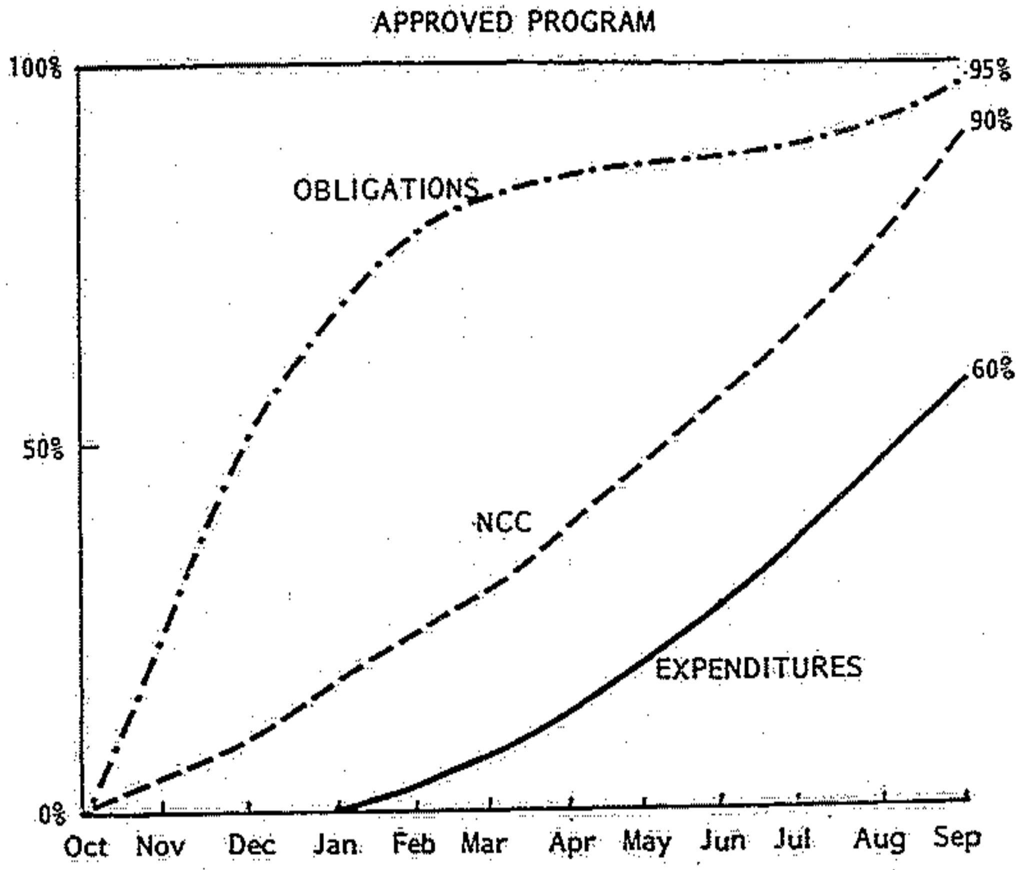

Figure VIII.3. SDIO Fiscal Projections for FY 1986

NCC is a sound financial parameter related to performance. NCC are costs incurred during a given period representing liabilities for goods and services received, other assets acquired and performance accepted, whether or not payment has been made. In essence, the SDIO views NCC data as more meaningful execution data since it reflects work actually accomplished and actual government liability. This data articulates in real-time, the debts being incurred by the SDIO for research efforts, materials, deliveries, etc. NCC is closely related to accrual cost accounting procedures used in the private sector. To date, NCC has proven to be a much more meaningful management tool than obligations or expenditures.

APPENDIX A

POSSIBLE SOVIET RESPONSES TO SDI

APPENDIX A

POSSIBLE SOVIET RESPONSES TO SDI

A.1 INTRODUCTION AND SCOPE

The following section responds to the Congressional request (Sec. 223) of the FY 1986 Appropriations Bill to address:

- What probable responses can be expected from potential enemies should the Strategic Defense Initiative (SDI) programs be carried out to procurement and deployment, such as what increase may be anticipated in offensive enemy weapons in an enemy's attempt to penetrate the defensive shield by increasing the numbers of qualities of its offensive weapons;

- What can be expected from potential enemies in the deployment of weapons not endangered by multi-layered ballistic missile defenses, such as cruise missiles and low trajectory submarine-launched missiles; and

- The degree of the dependency of success for the Strategic Defense Initiative upon a potential enemy's anti-satellite weapons capability.

Although the problem of predicting Soviet responses to possible procurement and deployment of a US strategic defense system is extraordinarily difficult, the Strategic Defense Initiative Organization (SDIO) has developed a methodology and an organizational structure which seeks to ensure that likely countermeasures and responsive threats are understood and evaluated throughout the technical evolution of the SDI.

Any deployed defensive system would be required to operate against a variety of threat types and force levels. A defense system must, however, be capable of achieving the SDI mission objectives against the full spectrum of threats that

might emerge over its operating lifetime, including responsive threats of all types. Accordingly, a variety of threats must be considered based on possible alternative attack strategies and tactics.

The SDIO recognizes that a comprehensive understanding of these threats is important for the development of a robust and survivable strategic defense system.

A.2 METHODOLOGY

The SDI Organization has adopted a two part program to ensure that defensive system architectures and technology programs are sufficiently robust to achieve mission objectives, regardless of the form of the Soviet response. First, the SDI has established and will maintain, with the coordination of the Intelligence Community, the baseline responsive threat to a developed SDI-type ballistic missile defense system. The Intelligence Community provides analytic intelligence and threat definition support to the SDI on projected Soviet (and other) ballistic missile and defense suppression (attacks on the defensive system) threats to various types of future US defensive systems.

Second, in order to maintain system design objectivity, the SDIO has also established "Red Teams" to independently examine and assess technical counters to proposed strategic defense systems and technologies. Several Red Teams, each consisting of a group of hand-picked technical experts, have been established to develop and evaluate technical counters to specific SDI system concepts and components. These countermeasures will be presented to appropriate "Blue Teams" which will consider their impact and propose ways to mitigate the countermeasure effects. Continuing Red Team/Blue Team interactions ensure that countermeasures are considered on a continuing basis during all stages of the R&D/system design process.

Red Team analyses are useful since they identify credible countermeasures to defensive systems and also those countermeasures which are less credible because they are technically, politically, militarily or economically difficult. Both of these imputs are essential to the defense system designer. The first helps him to design a system which is robust to likely Soviet countermeasures; the second minimizes unproductive responses to threats that are not credible. Independence is maintained by separating the responsibility for conducting the countermeasure analysis process from the defense system designers. This ensures that the countermeasures threat is not constrained in any way by the vested interests of the system designers.

The overall approach of coordinated threat definition plus Red Team interactions is designed to integrate the most accurate and up-to-date intelligence analysis with detailed technical countermeasure analysis to assist the SDIO and the defense designers in understanding technical responses to a particular system or component. The process established will ensure that credible countermeasures and threats are continuously reevaluated and applied to technology development and system design so that any resultant strategic defense could successfully operate in whatever environment the opponents may create.

A.3 EXAMPLE OF RED TEAM RESULTS

The purpose of a Red Team is to provide sound technical evaluations of countermeasures and to be an advocate which ensures that countermeasures are taken into acount by SDI development programs. The example results given here are intended to demonstrate how Red Teaming works. The process is being applied in various SDI technical areas.

A.3.1 Approach

A Red Team process was formulated to evaluate countermeasures to the High Endoatmospheric Defense System (HEDS).

During the period from April to June 1984, the evaluations teams were organized, their respective duties and responsibilities were outlined, and organizational meetings were conducted. An Umpire Team decision was made to conduct the process in a phased manner.

During Phase I, which commenced in June and lasted through early November 1984, the Red Team concentrated on developing candidate countermeasures to HEDS.

Phase II (November 1984 to March 1985) consisted of continued Red Team definition of HEDS countermeasures along with an initial Blue Team assessment of the Red Team countermeasure analyses performed in Phase I.

During the final phase (March through June 1985) of Round I, the Umpire Team Secretariat and Umpire Team completed their assessments of the HEDS countermeasures and countermeasure responses and developed recommendations for consideration by the U.S. Army BMD Program Manager (BMDPM). The recommendations were of three basic types: include the countermeasures in the threat; disregard the countermeasures; or have the Umpire Secretariat, Red, and Blue Teams perform additional analyses during a second round to settle unresolved issues and sharpen the results of Round I. The second round is currently ongoing and will conclude in June 1986.

A.3.2 Summary of Results

In Phase I, the Red Team developed a list of potentially stressing countermeasures to a HEDS that was assumed to be preceded by another defense tier. The major portion of the Red Team effort involved the design of two different suites of countermeasures. Each countermeasure suite employed at least one particular type of decoy design and incorporated a number of other penetration aids. The Red Team determined how effective these countermeasure suites needed to be to meet offense goal criteria.

At the completion of Phase I, the Umpire Team considered the set of 28 countermeasures identified by the Red Team and decided that the Blue Team should develop a response to 15 of these countermeasures. The Umpire Team assessed each of the 28 Red Team countermeasures in the areas of technical risk, effectiveness, and offense confidence that the countermeasure would work. Then the umpires made observations, conclusions and recommendations.

In Phase II, the Red Team focused its analysis efforts on countermeasures not included in the countermeasure suites. The Blue Team developed its initial response to the Phase I countermeasures proposed by the Red Team. The Blue Team also determined how well the HEDS needed to perform against offense decoys in order to meet the defense goal. In addition, the Blue Team developed specific defense responses to counter the countermeasure suites and other potential countermeasures.

In Phase III, the Umpire Team assessed Blue Team responses to the Red Team countermeasures, and as a consequence of this assessment identified requirements for additional work and analyses by the Red Team and Blue Team. In the opinion of the Umpire Team, Blue Team responses to the countermeasure suites clearly stressed the original design of the suites, requiring the Red Team to reconsider the designs. On the other hand, Blue Team responses to certain other countermeasures required additional analysis also.

The Umpire Team also identified areas not considered by the Red and Blue Teams in Round I. The Blue Team did not have sufficient time during Phase II to respond to all of the Red Team countermeasures and consequently, in the second round of the analyses, the Blue Team was directed to do so. The Red Team, in addition to reconsidering the design of the countermeasure suites, was to expand their analysis into other areas.

A.3.3 Round I Findings

The Red Team process has resulted in an improved understanding of countermeasures and countermeasure responses. New ideas for countermeasures and countermeasure responses were identified, evaluated, and are being considered in the HEDS system design. The analyses have demonstrated that simple decoys or poorly designed elaborate decoys will not work against the technologically sophisticated components used in the HEDS system.

A.3.4 Results

Significant results from Round I have been identified, and requirements have been developed for additional analysis by the Red and Blue Teams. Round I efforts have resulted in a HEDS design that is more robust to possible Soviet countermeasures, and it is expected that the second round of the process will produce additional significant modifications to the HEDS design. The Red Team process is now being used in other SDI technical areas.

A.4 CONCLUSION

Clearly, the scope of the requirement to define potential Soviet responses to SDI over such a long time and over such a large range of possible actions is unprecedented in this country.

The methodology and organizational structure which SDIO has developed seeks to ensure that all potential responses are evaluated throughout the technical evolution of the SDI. In addition, a Red Team function has been established to see that countermeasures are taken into account in all aspects of the program. This iterative projection and evaluation of Soviet efforts to counter the SDI is designed to ensure that the SDI system architectures and technology programs are sufficiently robust to achieve mission objectives, regardless of the form

of the Soviet response. The process is systematic, thorough, intellectually defensible, and consistently applied across all SDI system design projects.

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APPENDIX B

SDI AND THE ALLIES

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B.1 CONSULTATIONS WITH ALLIES ON SDI

B.1.1 Congressional Reporting Requirements

This appendix responds to the Congressional requirement to include in the annual report on Strategic Defense Initiative programs "the status of consultations with other member nations of the North Atlantic Treaty Organization, Japan, and other appropriate Allies concerning research being conducted in the Strategic Defense Initiative program."

B.1.2 SDI and Allied Security

When President Reagan announced the Strategic Defense Initiative, he made clear from the outset that the program was designed to enhance Allied as well as U.S. security. Thus, the SDI will examine defenses against all ballistic missiles, no matter what their range or armament, and can only strengthen the U.S. commitment to the defense of European and other Allies.

In line with that commitment, the U.S. government has been engaged in close and continuing consultations with its Allies on the Strategic Defense Initiative since the inception of the research program. The U.S. also conducts ongoing discussions with the Allies on the exchanges with the USSR that bear on the SDI program at the Defense and Space Talks in Geneva. Those consultations will continue throughout the SDI research program. Furthermore, if the necessary research criteria are met, the U.S. will consult closely with its Allies regarding any future decision to develop and deploy defenses against ballistic missiles.

Contacts with the Allies on the SDI go well beyond consultation; the U.S. looks forward to the broadest possible Allied involvement in actual SDI research activity. As a result, in March 1985 Secretary Weinberger invited the NATO

Allies, as well as Australia, Israel, Japan and South Korea, to participate directly in SDI research.

B.1.3 Bilateral Consultations on the SDI

Consultations with friends and Allies on the SDI broadened and deepened throughout 1985. Indeed, such discussions are a regular feature of numerous meetings with Allied officials at all levels, both in Washington and abroad. The following offers a brief summary of some of the more noteworthy contacts.

President Reagan, Secretary of Defense Weinberger and Secretary of State Shultz have discussed the program in virtually all their bilateral meetings on security matters with their Allied counterparts. High-level and mid-level National Security Council, Department of Defense, Department of State, and ACDA officials also held extensive bilateral consultations with Allied governmental, military and parliamentary leaders, both in the United States and in Allied capitals.

The practice, begun in 1984, of periodic interagency briefings in Allied and friendly capitals has continued. Those briefings have covered Soviet activities in strategic offense and defense, the defense and arms control policy implications of the SDI, and the scope and progress of the SDI research program. The briefing teams included representatives of the National Security Council, Office of the Secretary of Defense, Department of State, and the Arms Control and Disarmament Agency. They visited Denmark, Norway, Spain, the Netherlands and the Federal Republic of Germany in March 1985; Japan in April; Singapore, Malaysia, Indonesia and Thailand in May; and Turkey, China, South Korea and Australia in June of that year. In January 1986, a team visited Finland, Sweden, and Switzerland.

B.1.4 Multilateral Consultations on the SDI

Multilateral consultations with groups of Allied governments also intensified at all levels in 1985. The President

discussed the Strategic Defense Initiative at the May 1985 Economic Summit and at the United Nations in October with the heads of government of Canada, the Federal Republic of Germany, Italy, Japan and the United Kingdom. The President also briefed the NATO Allies--most of which were represented by their heads of government--immediately after his November meeting with General Secretary Gorbachev. That briefing included a detailed discussion of his exchanges with Gorbachev on the SDI.

The ministerial meetings of NATO's Nuclear Planning Group, in Luxembourg in March and Brussels in October 1985, featured extensive discussions of the SDI. The Ministers were briefed on the progress of the SDI research program, on the defense and arms control policy implications of the SDI, and on Soviet activities in strategic offensive and defensive systems. The communique issued at the close of the Luxembourg meeting underscored NATO Allies' support for the SDI:

> "We have continued the comprehensive consultations on the political and strategic implications of the United States' Strategic Defense Initiative (SDI). This is designed to establish whether recent advances in technologies could offer the prospect of significantly more effective defense against ballistic missiles. We support the United States research program into these technologies, the aim of which is to enhance stability and deterrence at reduced levels of offensive nuclear forces. This research, conducted within the terms of the ABM Treaty, is in NATO's security interest and should continue. In this context, we welcome the United States invitation for Allies to consider participation in the research program."
>
> "We noted with concern the extensive and long-standing efforts in the strategic defense field by the Soviet Union which already deploys the world's only ABM and antisatellite systems. The United States strategic defense research program is prudent in the light of these Soviet activities and is also clearly influenced by the treaty violations reported by the President of the United States."

The United States also consulted with Allied leaders on the Strategic Defense Initiative and other SDI related issues being addressed in the Defense and Space Talks in Geneva. Specifically, this took place at the ministerial meetings of the North Atlantic Council and Defense Planning Committee in June and December 1985. Further consultations took place below the ministerial level in several NATO fora throughout 1985. In addition, Secretary of State Shultz, SDIO Director Lieutenant General Abrahamson and Special Advisor to the President Paul Nitze discussed the Strategic Defense Initiative with NATO parliamentarians at the North Atlantic Assembly in San Francisco in October 1985.

B.1.5 Foreign Participation in SDI Research

Secretary Weinberger's March 1985 invitation to a number of Allied and friendly nations to participate in SDI research led to a series of continuing bilateral discussions with several Allies on potential research involvement, briefings to their delegations who have come to Washington, visits for these groups to SDI research facilities and SDIO technical team visits to Allied countries. The object of this multifaceted dialogue has been to address the various procedural concerns on each side, and to identify areas of SDI research for possible participation, consistent with U.S. security interests, law, and international obligations including the ABM Treaty.

Allied firms are free to seek unclassified SDI contracts and subcontracts, with no action required by their governments, except as may be necessary, for example, under U.S. export control laws and regullations. Firms in those countries with which the U.S. has the appropriate bilateral security agreements may seek classified SDI contracts as well. Some Allied government involvement would be required, in that case, to ensure compliance with those agreements: the potential contractor must be cleared by its government; the classified information involved in the contract must be approved for release by the

United States to that government; and that information must be transferred through government-to-government channels.

Nevertheless, the U.S. believes that mutually beneficial Allied participation would be facilitated by new government-to-government agreements concerning SDI research involvement. This type of accord would lay down agreed ground rules regarding the basic terms and conditions of participation in SDI research, covering such recurring issues as protection of classified information, control of technology transfer, rights to use research results, etc. On 6 December 1985, Secretary Weinberger and British Defense Minister Michael Heseltine signed such an agreement in the form of a bilateral Memorandum of Understanding (MOU). MOUs were signed by the Federal Republic of Germany and Israel on 27 March and 6 May, respectively.

Allied SDI research involvement will be based on technical merit. The U.S. has made clear to its Allies that there can be no guarantee of a certain level of effort. It is expected, however, that Allied scientific and technical expertise can make a substantial contribution to the SDI research program, which will help accelerate its schedule and reduce overall costs. In addition, research participation will directly benefit the Allies involved through the gains inherent in such a deeper understanding of the military and technical basis for defense against ballistic missiles.

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APPENDIX C

COMPLIANCE OF THE STRATEGIC DEFENSE INITIATIVE WITH THE ABM TREATY

APPENDIX C

COMPLIANCE OF THE STRATEGIC DEFENSE INITIATIVE WITH THE ABM TREATY

INTRODUCTION AND SCOPE

This appendix addresses compliance with the ABM Treaty of activities under the Strategic Defense Initiative and related programs. The treatment of devices based on "other physical principles" is discussed. The existing process for ensuring compliance with Strategic Arms Limitation (SAL) Agreements, including organizational responsibilities and reporting procedures and their application to SDI and the ABM Treaty, is also described.

POLICY

There are four major points to be made regarding United States policy on compliance with the ABM Treaty.

First, the SDI research program is being conducted in a manner fully consistent with all U.S. Treaty obligations. The President has directed that the program be formulated in a fully compliant manner, and the DoD has planned and reviewed the program (and will continue to do so) to ensure that it remains compliant.

Second, the need for greater precision in our understanding of the limitations of the ABM Treaty recently caused the U.S. Government to reexamine the Treaty as it relates to future systems based on "other physical principles." These devices are addressed in an agreed statement to the Treaty as "ABM systems based on other physical principles and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars." This review led to the judgment by the President that a reading of the ABM Treaty that would allow the development and testing of such systems based on other physical principles, regardless of basing mode, is fully justified.

The SDI program was originally structured in a manner that was designed to permit it to achieve critical research objectives while remaining consistent with a more narrow interpretation of the ABM Treaty. This being the case, in October 1985, while reserving the right to conduct the SDI program under the broad interpretation at some future time, the President deemed it unnecessary to restructure the SDI program towards the boundaries of the ABM Treaty which the U.S. could observe.* Consistent with that determination, the Administration applies the more restrictive treaty interpretation as a matter of policy, although we are not legally required to do so, in evaluating the experiments in the SDI program. Therefore, statements in this appendix regarding compliance with treaty provisions should be understood as based upon the restrictive interpretation. It should be equally understood, however, that the President believes that the broader interpretation is fully justified.

Third, because there are areas** which are not fully defined in the ABM Treaty, it is necessary in some cases to

* This restrictive interpretation treats ABM devices based on other physical principles and capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars as "ABM components" within the meaning of Article II of the Treaty, and therefore subject to the provisions of the Treaty, including Article V.

** An example within the restrictive interpretation of the Treaty is the subject of components. ABM components are defined in the Treaty as "currently" (i.e., 1972) consisting of ABM missiles, launchers, and radars. But there is no agreed definition of what constitutes an "ABM component" based on future technology, beyond the guidance in Agreed Statement D: "In order to ensure fulfillment of the obligation not to deploy ABM systems and their components except as provided in Article III of the Treaty, the Parties agree that in the event ABM systems based on other physical principles and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars are created in the future [i.e., after 1972], specific limitations on such systems and their components would be subject to discussion in accordance with Article XIII and agreement in accordance with Article XIV of the Treaty."

infer specific standards for compliance. Four of the more important working principles of this review used to establish such standards are that:

- Compliance must be based on objective assessments of capabilities which support a single standard for both sides and not on the subjective judgments as to intent which could lead to a double standard of compliance.
- The ABM Treaty prohibits the development, testing, and deployment of ABM systems and components that are sea-based, space-based, air-based, or mobile land-based. However, regarding devices, the Treaty does permit research short of field testing of a prototype ABM system or component. This is the type of research that will be conducted under the SDI program.
- New technologies and devices should not be subjected to more strict standards than existing systems.
- The ABM Treaty, of course, restricts only defenses against strategic ballistic missiles; it does not apply to defenses against non-strategic ballistic missiles or cruise missiles.

Fourth, we have not in this report considered Soviet violation of the ABM Treaty. The United States has reserved the right to respond in appropriate ways, some of which may eventually bear on the Treaty constraints as they apply to the United States. The United States Government must guard against permitting a double standard of compliance, under which the Soviet Government would expect to get away with violations of various provisions of arms agreements while the U.S. continues to comply with all provisions.

OVERALL COMPLIANCE ASSESSMENT

The entire SDI research program is being conducted in compliance with the ABM Treaty. The SDI program consists of near-term technology research projects and major experiments. The research projects directly support the major experiments by providing the necessary technologies. These research activities are well defined and clearly compliant. The major experiments, most of which are to be conducted in later years, are also being planned to be fully compliant. Experiments can demonstrate technical feasibility without involving ABM systems or components or devices with their capabilities. Thus, useful and compliant experiments, in both "mobile" and "fixed land-based" configurations are allowed.

EXISTING COMPLIANCE PROCESS FOR SDI

DoD has in place an effective compliance process (established in 1972 after the signing of the SALT I agreements), under which key offices in DoD are responsible for overseeing and will continue to oversee SDI compliance with all existing strategic arms control agreements. Under this process the SDIO and Services ensure that the implementing program offices adhere to DoD Compliance Directives and seek guidance from offices charged with oversight responsibility.

Specific responsibilities are assigned by DoD Directive 5100.70, 9 January 1973, Implementation of SAL Agreements. The Under Secretary of Defense for Research and Engineering (USDRE) ensures that all DoD programs are in compliance with existing SAL agreements. The Service Secretaries, Chairman of the Joint Chiefs of Staff and Agency Directors ensure the internal compliance of their organizations. The DoD General Counsel provides advice and assistance with respect to the implementation of the compliance process and interpretation of SAL agreements.

DoD Instruction S-5100.72 establishes general instructions, guidelines, and procedures for ensuring the continued

compliance of all DoD programs with the existing arms control agreements. Under these procedures questions of interpretation of specific agreements are to be referred to the USDRE to be resolved on a case-by-case basis. No project or program which reasonably raises an issue as to compliance can enter into the testing, prototype construction, or deployment phases without prior clearance from the USDRE. If such a compliance issue is in doubt, USDRE approval shall be sought. In consultation with the DoD General Counsel, OASD/International Security Policy and OJCS, the USDRE applies the provisions of the agreements, as appropriate. Military departments and DoD agencies, including SDIO, are to certify internal compliance quarterly and establish internal procedures and offices to monitor and ensure internal compliance.

In 1985, the United States began discussions with Allied governments regarding technical cooperation on SDI research. All cooperative SDI research agreements will be implemented in a manner consistent with U.S. international obligations including the ABM Treaty. The Administration has adopted guidelines to ensure that all exchanges of data and cooperative research ventures are conducted in full compliance with the ABM Treaty obligations not to transfer ABM systems or components limited by the Treaty, nor to provide technical descriptions or blueprints specifically worked out for the construction of such systems or components.

CATEGORIES OF TREATY COMPLIANT ACTIVITIES

There are three basic types of activity that are permitted in compliance with the ABM Treaty. The SDI major experiments described below are grouped according to these categories.

Category 1 - Conceptual Design or Laboratory Testing

This activity precedes field testing and was considered during the ABM Treaty negotiations to be research that was not verifiable by National Technical Means (NTM) and not subject to Treaty limits.

Category 2 - "Field Testing" of Devices that are not ABM Components or Prototypes of ABM Components

As noted earlier, Article V prohibits the development, testing, and deployment of ABM systems or components which are sea-based, air-based, space-based, or mobile land-based.

The negotiating record of the ABM Treaty shows it was clearly understood in 1972 that "development" begins when field testing is initiated on a prototype of an ABM component. The definition of "development" applied to the Article V limitations results in the prohibition of field testing of ABM systems or components, or their prototypes which are other than fixed land-based. Thus, SDI field tests of space-based or other mobile-based devices cannot involve ABM components or prototypes. All SDI Category 2 experiments must meet this criterion. For any device to be limited by the ABM Treaty, whether labeled "prototype" or some other term of art, it must constitute an ABM system or component (an ABM interceptor missile, ABM launcher or ABM radar) or be capable of substituting for such an ABM component.

"ABM systems and components" are defined in Article II as follows:

> For the purpose of this treaty an ABM system is a system to counter strategic ballistic missiles or their elements in flight trajectory, currently consisting of: (a) ABM interceptor missiles, which are interceptor missiles constructed and deployed for an ABM role, or of a type tested in an ABM mode; (b) ABM launchers, which are launchers constructed and deployed for launching ABM interceptor missiles; and (c) ABM radars, which are radars constructed and deployed for an ABM role, or of a type tested in an ABM mode.

We are applying the rule that all SDI "field tests" not involving fixed, land-based devices must not be conducted in an "ABM mode." The term "tested in an ABM mode" is specifically addressed in a classified Agreed Statement negotiated in 1978 by the U.S. and U.S.S.R. and in the Standing Consultative Commission. That agreement provides in part, that an interceptor missile is considered to be "tested in an ABM mode" if it has attempted to intercept (successfully or not) a strategic ballistic missile or its elements in flight trajectory. Likewise a radar is considered to be "tested in an ABM mode" if it performs certain functions such as tracking and guiding an ABM interceptor missile or tracking strategic ballistic missiles or their elements in flight trajectory in conjunction with an ABM radar which is tracking and guiding an ABM interceptor missile. "Strategic ballistic missiles or their elements in flight trajectory" include ballistic target-missiles with the flight trajectory characteristics of strategic ballistic missiles or their elements over the portions of the flight trajectory involved in testing.

Category 2 experiments must also meet the obligation of Article VI not to give non-ABM launchers, missiles, or radars capabilities to counter strategic ballistic missiles or their elements in flight trajectory.

Allowed Category 2 activities include tests of experimental devices to demonstrate technical feasibility and gather data prior to constructing a prototype of an actual ABM component or weapon system. Tests of non-ABM systems performing functions consistent with Treaty obligations (such as air defense and early warning) are also legitimate Category 2 activities.

Category 3 - "Field Testing" of Fixed Land-Based ABM Components

"Field Testing" of fixed land-based ABM components or systems is permitted as long as other Treaty provisions are met. Under Article IV all such tests must take place at agreed ABM

test ranges (for the U.S., White Sands Missile Range and Kwajalein Missile Range), and the total test launcher count must not exceed 15.

Other testing must comply with limitations in paragraph 2 of Article V on launcher capabilities as follows:

> Each party undertakes not to develop, test, or deploy ABM launchers for launching more than one ABM interceptor missile at a time from each launcher, nor to modify deployed launchers to provide them with such a capability, not to develop, test, or deploy automatic or semi-automatic or other similar systems for rapid reload of ABM launchers.

Agreed Statement E prohibits "developing, testing, or deploying ABM interceptor missiles for delivery by each ABM interceptor missile or more than one independently guided warhead."

Summary

The SDI projects and experiments have been reviewed to ensure that they will be conducted in accordance with one of the three categories of activities permitted by the Treaty.

The Services and the SDIO are obligated to plan and implement these experiments in a compliant manner. Many of the SDI devices do not use traditional technology, but are "based on other physical principles" (such as lasers). In these cases, we have reviewed them by considering their capability to substitute for traditional ABM components and whether they will be "tested in an ABM mode" by analogy to the 1978 Agreed Statement (which does not address devices based on new technology).

COMPLIANCE ASSESSMENT

The entire SDI program has been reviewed to ensure compliance with the ABM Treaty. The bulk of the near-term

effort consists of technology research projects which support major experiments to be conducted by the SDI program. Most technology research projects fall in Category 1, some in Category 2, and none in Category 3. Sixteen major experiments and their basis for compliance (thirteen are in Category 1 or 2 and three are in Category 3) are summarized below. Three major new experiments are considered: the Ground-Based Free Electron Laser (GBFEL), the High Brightness Relay (HIBREL), and the Neutral Particle Beam (NPB). Two experiments, the Long Wavelength Infrared (LWIR) Probe and the Integrated Demonstration, are not considered this year, because they are not funded in the requested program. Other experiments have been substantially revised since last year.

Category 1 and 2 Major Experiments

These thirteen experiments involve devices which are not ABM components or their prototypes and are not capable of substituting for ABM components. These include the six Directed Energy Weapon (DEW)-related experiments and seven Surveillance, Acquisition, Tracking and Kill Assessment (SATKA) and Kinetic Energy Weapon (KEW) experiments.

The six DEW experiments are: the ALPHA/LODE/LAMP; high power technology integration experiment of MIRACL and large beam director; the Space Acquisition, Tracking, and Pointing (ATP) experiment; the Ground-Based Free Electron Laser (GBFEL); the High Brightness Relay (HIBREL); and the Neutral Particle Beam (NPB). The SATKA projects are: the Boost Surveillance and Tracking System (BSTS) experiment; the Space Surveillance and Tracking System (SSTS) experiment; and the Airborne Optical Adjunct (AOA) experiment. The KEW projects are: the Space-Based Kinetic Kill Vehicle (SBKKV) experiment, the Hypervelocity Rail Gun experiments, and the Significant Technical Milestone (STM).

ALPHA is a ground-based laser device designed to demonstrate the feasibility of high power infrared (IR) chemical lasers for space-based applications. The Large Optics Demonstration Experiments (LODE) and Large Advanced Mirror Program (LAMP) are to demonstrate critical beam control and large lightweight space optics technologies respectively, in a series of ground-based experiments simulating the space environment. All of these tests are under-roof experiments using devices incapable of achieving ABM performance levels. (Category 1)

The MIRACL laser and the Sea Lite Beam Director subsystems from the former Navy Sea Lite program will be integrated into an experimental device for ground-based lethality testing against targets at White Sands Missile Range. We will determine, in a ground experiment, whether we can efficiently integrate a laser and beam director, which (separated or combined) are not capable of substituting for an ABM component. The power, optics, and laser frequency are not compatible with atmospheric propagation at ranges useful for ABM applications. Experiments are planned against ground-based, static targets. The device is not a prototype nor is it "ABM capable." In addition, a dynamic lethality experiment is planned against a modified first stage of a non-strategic ballistic missile at very close range (10-20 km) just after the missile has been launched from a point close to the MIRACL laser. Since MIRACL is fixed, land-based and located at the White Sands Missile Test Range, an ABM Test Site, should it ever be considered to be "tested in an ABM mode," it would remain Treaty compliant. (Category 2)

The newly constituted Space Acquisition, Tracking and Pointing (ATP) experiment program will concentrate on a series of experiments, using the shuttle, to demonstrate, with increasing degrees of difficulty, technologies required for acquisition, tracking, and pointing of weapons and sensors for space- and ground-based applications. Current plans call for

experiments over the next few years, using technologies which are only part of the set of technologies ultimately required for ABM capability. These devices will also not be capable of achieving ABM performance levels. As these plans become better defined, they will be reviewed to ensure they are in compliance. (Category 1/2)

The Ground-Based Free Election Laser program includes the fabrication of an experimental high power laser to perform an uplink experiment to an instrumented spacecraft which will measure beam properties. Longer term plans include upgrading this experimental facility to higher power. Should it achieve ABM capability, the fixed, Ground-Based FEL still will be in compliance with the ABM Treaty. (Category 2/3)

The High Brightness Relay (HIBREL) project consists of a series of experiments to demonstrate the feasibility of relay mirrors in space for ground-based lasers. The experiments are not yet well defined; however, the instrumented mirrors aboard the shuttle will only be capable of handling light from low power laser beams. The experiments will use technologies which are only part of the set of technologies ultimately required for ABM capability. These devices will not be capable of achieving ABM performance levels. (Category 2)

The Neutral Particle Beam Technology Integration experiment is to investigate the technologies needed to perform midcourse discimination or detect nuclear material. This experiment will be conducted in space at low average power using nearby, co-orbital, instrumented targets, and the device will not be capable of autonomously acquiring or tracking ballistic targets. Because of such limitations, this experimental device will not have ABM capabilities. This experiment will not be a test in an ABM mode. (Category 2)

The Boost Surveillance and Tracking System (BSTS) experiment is a space-based experiment (which is not yet fully defined) to demonstrate technology capable of upgrading the current early warning system. This experiment will, if successful, also permit a decision to be made on the applicability of more advanced technology for ABM purposes. The BSTS experimental device will not be a prototype of an ABM component. The experiment will determine if sufficiently sensitive tracking and signature data can be collected on-orbit against the earth's background. The BSTS experimental device will be limited in capability so that it cannot substitute for an ABM component, but will be capable of performing early warning functions, which are permitted by the Treaty. For example, the experimental BSTS will collect ballistic missile plume data, but it will not be capable of a real-time data processing for handing-off to a boost-phase interceptor. Other capabilities may be limited as well. (Category 2)

The space-based Space Surveillance and Tracking System (SSTS) experimental program has been significantly cut back since last year's evaluation and is now again undergoing an extensive revision. The objectives of this SSTS experiment are to (1) demonstrate technology capable of upgrading the current U.S. Space Detection and Tracking System (SPADATS) and (2) permit a decision to be made on the applicability of more advanced technology for ABM purposes. This experiment will demonstrate the collection of tracking and signature data on a number of space objects against the earth's upper atmosphere and space backgrounds. A data gathering satellite is scheduled for launch in the early 1990s. Its capability will be significantly less than that necessary for ABM performance levels or to substitute for an ABM component. (Category 2)

The Airborne Optical Adjunct (AOA) experiment will demonstrate the technical feasibility of long wavelength infrared (LWIR) acquisition, tracking, and discrimination of strategic

ballistic missiles from an airborne platform to support a ground-based radar. The airborne platform will initially be a Boeing 767; the ultimate airborne platform is yet to be determined. The AOA experiment has been reduced in scope because of cost considerations to a single, passive sensor. The AOA experimental device will not be capable of substituting for an ABM component due to its sensor and platform limitations. As part of the feasibility demonstration, the AOA experimental device will observe ballistic missile tests flown into the Kwajalein Missile Range (KMR). Any increase in the performance of the AOA experimental device or tests involving ABM interceptor missiles will require prior approval. (Category 2)

The purpose of the Space-Based Kinetic Kill Vehicle (SBKKV) project (which is not fully defined) is to establish the technology for chemically propelled space-based interceptors. This experiment will permit a decision to be made on the applicability of more advanced chemically based technology for ABM purposes. The demonstration hardware for any space-based experiment will not be an ABM component, will not be capable of substituting for an ABM component, and will not be tested in an ABM mode. There will be no intercepts of strategic ballistic missiles or their elements in flight trajectory in a space-based experiment. Intercepts of certain orbital targets simulating anti-satellite weapons can clearly be compatible with these criteria. (Category 2)

The Ground-Based Hypervelocity Railgun (GBHRG) experiment (which is not fully defined) is intended to validate the weapon potential of a hypervelocity gun. Several types of projectiles will be fabricated to demonstrate that precision guided munitions can be successfully launched from hypervelocity guns. The test devices will not be ABM components and will not have ABM capabilities. They will demonstrate the capability to launch unguided and guided projectiles at hypervelocities from ground-based rail guns within a laboratory environment and will not involve "testing in an ABM mode." (Category 1)

The Space-Based Hypervelocity Rail Gun (SBHRG) experiment is not fully defined and has been significantly cut back from last year's report. It will test individual technical elements of a rail gun concept which require testing in space but will not include the space operation of a complete rail gun. (Category 2)

The Significant Technical Milestones (STM) experiment involves a single launch device that puts two vehicles in closely related orbits. The vehicles will be maneuvered relative to each other to obtain sensor guidance and navigation data. The experiment is a multifaceted exoatmospheric experiment involving research into the area of vehicle dynamics, guidance, and sensor sciences. The devices utilized in this experiment are not ABM components, do not have any ABM capability, and the experiment does not involve a test in the ABM mode. (Category 2)

Category 3 Experiments

These three experiments involve tests of fixed ground-based "ABM components" at agreed ABM Test Ranges.

The High Endoatmospheric Defense Interceptor (HEDI) project is to demonstrate the capability to intercept and negate strategic ballistic missile warheads within the atmosphere using a nonnuclear interceptor missile. Flight tests will be performed at White Sands Missile Range (WSMR) and Kwajalein Missile Range (KMR). All flight tests will be from fixed ground-based launchers without the capability of being rapidly reloaded or launching more than one interceptor missile. The interceptor missiles will not be capable of delivering more than one independently-guided warhead. All activity will be conducted in a manner permitted by the ABM Treaty. (Category 3)

The Exoatmospheric Reentry-Vehicle (RV) Interceptor Subsystem (ERIS) is intended to engage incoming RVs prior to entry into the atmosphere. This is an allowed test of a nonnuclear interceptor missile. All interceptor missile flight

tests are to be conducted from fixed ground-based launchers at KMR. The planned flight tests include launch of the first stage, launch of all stages without homing, homing against a point in space, and hit-to-kill against targets. Fixed ground-based launchers will be incapable of launching more than one interceptor missile and will not be rapidly reloadable. The ERIS interceptor missile will not be capable of delivering more than one independently-guided warhead. (Category 3)

The Terminal Imaging Radar (TIR) will be an X-band ABM radar which may be tested in an ABM mode in full compliance with the terms of the ABM Treaty. This fixed, land-based radar will be tested at a designated ABM test range (i.e., KMR). The objective is to demonstrate performance and effectiveness of an X-band ABM radar. TIR will be permanently installed in an existing radar building and will require this building for structural support. (Category 3)

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APPENDIX D

GLOSSARY OF SDI DEFINITIONS

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Acquisition	The process of searching for and detecting a potentially threatening object in space. An acquisition sensor is designed to search a large area of space and to distinguish potential targets from other objects against the background of space.
Algorithm	Rules and procedures for solving a problem.
Anti-Ballistic Missile (ABM) System	A missile designed to intercept and destroy a strategic offensive ballistic missile or its reentry vehicle.
Anti-Satellite (ASAT) Weapon	A weapon designed for or capable of destroying satellites in space. The weapon may be launched from the ground, from an aircraft, or be based in space. The target may be destroyed by either a nuclear or conventional explosion, by collision at high speed, or by a directed-energy beam.
Architecture	Description of all functional activities to be performed to achieve the desired level of defense, the system elements needed to perform the functions, and the allocation of performance levels among those system elements.
Ballistic Missile	A pilotless vehicle propelled into space by rocket engines. Thrust is terminated at a pre-designated time after which the missile's reentry vehicles are released and follow free-falling trajectories toward their targets under the influence of gravity. Much of a reentry vehicle's trajectory will be above the atmosphere.
Battle Management	Includes assets to perform the computations to direct target selection and fire control, perform kill assessments, provide command and control, facilitate communication, and assist a variety of military users in the accurate determination of their positions.
Boost Phase	The first phase of a ballistic missile trajectory during which it is being powered by its engines. During this phase, which usually lasts between 3-5 minutes for an ICBM, the missile reaches an altitude of about 200 km whereupon powered flight ends and the missile

Boost Phase (Cont.)	begins to dispense its reentry vehicles. The other phases of missile flight, including mid-course and reentry, take up the remainder of an intercontinental ballistic missile's flight time of 25-30 minutes.
Booster	The rocket that "boosts" the payload to accelerate it from the earth's surface into a ballistic trajectory, during which no additional force is applied to the payload.
Brightness	As used in SDI, brightness is the measure of source intensity. To determine the amount of energy per unit area on a target, both source brightness and source-target separation distance must be specified.
Bus	The warheads on a single missile are carried on a platform of "bus" (also referred to as a post-boost vehicle).
Chaff	Strips of frequency-cut metal foil, wire, or metallized glass fiber used to reflect electromagnetic energy, usually dropped from an aircraft or expelled from shells or rockets as a radar countermeasure.
Chemical Laser	A laser in which chemical action is used to produce pulses of intense light.
Communication	Includes communication between two or more ground sites, between satellites, or between a satellite and a ground site.
Decoy	A device constructed to look and behave like a nuclear-weapon carrying warhead which is far less costly, much less massive, and can be deployed in large numbers to complicate defenses.
Directed-Energy	Energy in the form of atomic particles, pellets, or electromagnetic beams that can be sent long distances at, or nearly at, the speed of light.
Directed-Energy Weapon	A weapon that employs a tightly focused and precisely directed beam of very intense energy, either in the form of light (a laser) or of atomic particles traveling at velocities close to the speed of light (a particle beam weapon). (See also Laser and Particle Beam Weapon.)

Discrimination	The process of observing a set of attacking objects and determining which are decoys or other non-threatening objects.
Electromagnetic Gun	A gun in which the projectile is accelerated by electromagnetic forces rather than by an explosion, as in a conventional gun.
Endoatmospheric	Within the earth's atmosphere, generally considered altitudes below 100 km.
Engagement Time	The amount of time that a weapon platform takes to negate a given target. This includes not only firing at the target but all other necessary weapon functions involved that are unique to that particular target.
Excimer Laser	A laser in which emission is stimulated when a gas is shocked with electrical energy and the excited medium emits light when returning to a ground state.
Exoatmospheric	Outside the earth's atmosphere, generally considered altitudes above 100 km.
Fluence	The amount of energy per unit area on target. (It should be specified whether this is incident or absorbed fluence.)
Gamma Ray	Electromagnetic radiation resulting from nuclear transitions. Although incorrect, high-energy radiation, particular bremsstrahlung, is sometimes referred to as gamma radiation.
Hardening	Measures which may be employed to render military assets less vulnerable.
Hypervelocity Gun	A gun that can accelerate projectiles to 5 km per second or more; for example, an electromagnetic or rail gun.
Imaging	The process of identifying an object by obtaining a high-quality image of it.
Interception	The act of destroying a target.
Intercontinental Ballistic Missile (ICBM)	A ballistic missile with a range of 3,000 to 8,000 nautical miles. The term ICBM is used only for land-based systems to differentiate them from submarine-launched ballistic missiles, which are also considered strategic, though not necessarily intercontinental.

Intermediate-Range Ballistic Missile (IRBM)
: A land-based ballistic missile with a range 2,500 to 3,000 nautical miles. The range is less than that of an ICBM but greater than that of a short- or medium-range ballistic missile. Types of IRBMs currently deployed include the Soviet SS-20.

Kinetic Energy
: The energy from the momentum of an object, i.e., an object in motion.

Kinetic-Energy Weapon
: A weapon that uses a non-explosive projectile moving at very high speed to destroy a target on impact. The projectile may include homing sensors and onboard rockets to improve its accuracy, or it may follow a preset trajectory (as with a shell launched from a gun). The projectile may be launched from a rocket, conventional gun, or rail gun.

Laser
: (Light Amplification by the Stimulated Emission of Radiation) A device for producing an intense beam of coherent light. The beam of light is amplified when photons (quanta of light) strike atoms or molecules. These atoms or molecules are thereby stimulated to emit new photons (in a cascade or chain reaction) which have the same wavelength and are moving in phase and in the same direction as the original photon. A laser weapon may destroy a target by heating, melting, or vaporizing its surface.

Layered Defense
: A defense that consists of several sets of weapons that operate at different phases in the trajectory of a ballistic missile. Thus, there could be a first layer (e.g., boost-phase) of defense with remaining targets passed on to succeeding layers. (e.g. mid-course, terminal)

Leakage
: The percentage of warheads that get through a defensive system intact and operational.

Lethality
: Refers to the amount of energy, or other beam characteristic, required to eliminate the military usefulness of enemy targets by causing serious degradation (mission kill) or destruction (observable kill) of a target system.

Midcourse Phase
: That portion of the trajectory of a ballistic missile between the boost phase and the re-entry phase. During this phase of the missile trajectory the missile releases its warheads

Midcourse Phase (Cont.)	and decoys and is no longer a single object, but a swarm of RVs, decoys, and debris falling freely along pre-set trajectories in space.
Multiple Independently-Targetable Reentry Vehicle (MIRV)	A package of two or more reentry vehicles which can be carried by a single ballistic missile and guided to separate targets. MIRVed missiles employ a warhead dispensing mechanism, called a post-boost vehicle (PBV or "bus"), to target and release the warheads.
Neutral Particle Beam	An energetic beam of neutral atoms (no net electric charge). A particle accelerator moves the particles to nearly the speed of light.
Nonnuclear Kill	A kill that does not involve a nuclear detonation.
Nuclear Directed Energy Weapon	Directed energy weapons where the source of energy is a specially designed nuclear explosive.
Particle Beam	A stream of atoms or subatomic particles (electrons, protons, or neutrons) accelerated to nearly the speed of light.
Particle Beam Weapon	A weapon that relies on the technology of particle accelerators (atom-smashers) to emit beams of charged or neutral particles which travel at the speed of light. Such a beam could theoretically destroy a target by several means, e.g. electronics upset, electronics damage, softening/melting of materials, sensor damage, and initiation of high explosives. (Stable propagation of particle beams in the atmosphere has never been demonstrated.)
Passive Sensor	A sensor that only detects radiation naturally emitted (infrared radiation) or reflected (sunlight) from a target.
Pointing & Tracking	Once a target is detected, it must be followed or "tracked." When the target is successfully tracked, a weapon is pointed at the target. Tracking and pointing are frequently integrated operations.
Post-Boost Phase	The portion of a rocket trajectory following boost and preceeding reentry.

Post-Boost Vehicle	The portion of a rocket payload that carries the multiple warheads and has maneuvering capability to place each warhead on its final trajectory to a target (also referred to as a "bus").
Rail Gun	A weapon using electromagnetic launching to fire hypervelocity projectiles. Such projectile launchers will have very high muzzle velocities, thereby reducing the lead angle required to shoot down fast objects, lessening windage effects, and flattening trajectories in the atmosphere.
Reentry Vehicle (RV)	The part of a ballistic missile that carries the nuclear warhead to its target. The reentry vehicle is designed to reenter the earth's atmosphere in the terminal portion of its trajectory and proceed to its target.
Responsive Threat	A threat which has been upgraded in quality or quantity or with added protective countermeasures in response to a projected capability of defeating (all or part of) the threat.
Signature	The characteristic pattern of the target displayed by detection and identification equipment.
Surveillance	This includes tactical observations, strategic warning, and meteorological assessments, by optical, infrared, radar, and radiometric sensors on space-borne and terrestrial platforms.
Survivability	The capability of a system to avoid or withstand man-made hostile environments without suffering an irreversible impairment of its ability to accomplish its designated mission.
Terminal Phase	The final phase of a ballisitc missile trajectory, during which warheads and penetration aids reenter the atmosphere. This phase follows the end of the midcourse phase and continues until impact or arrival of the missile in the vicinity of the target.
Vulnerability	The characteristics of a space system which cause it to suffer a definite degradation (reduced capability to perform the designated mission) as a result of having been subjected to hostile environments. Vulnerability usually addresses a single space-system segment or element thereof. Of particular interest is the lowest level at which degradation effects, if any, are acceptable.

X-Rays	Electromagnetic radiation which results from either the release of energy from electrons changing orbits about the nucleus (discrete) or the inelastic collision of charged particles with the electromagnetic field of the nucleus.

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